3rd European Solar Thermal Energy Conference

estec 2007

Gerhard Rabensteiner

President of ESTIF,
Eurpean Solar Thermal Industry Federation

Welcome to estec2007!

Only few industries can claim growth rates as the ones solar thermal in Europe has experienced in recent years. Last year's market increased by more than 40% compared to 2005.

Several factors have contributed to this considerable development: Our industry has become much stronger and is actively developing new markets and creating new jobs. New products offer additional benefits to the end-user, new production methods have increased quality and lowered manufacturing costs, pre-assembled "kits" have made installations easier.

The unmistakable signs of global warming and the insecurity of supply of oil and gas have alerted citizens and policy makers alike. The solar thermal industry has been successful in offering concrete solutions to decrease our dependence on imported fossil fuels. More and more citizens choose solar thermal over oil and gas.

Through a steady support framework my home country, Austria, has become a success model for Europe: For five years in a row, no country has added more solar thermal capacity per capita than Austria. This has helped to develop a healthy solar thermal sector, with many new jobs in the industry, and with a highly skilled and growing research community, which is already working on the next generation of solar thermal solutions.

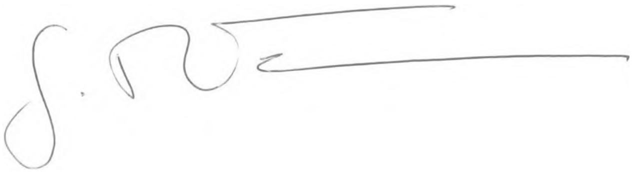
In March 2007 the heads of state of the 27 EU Member States agreed on a binding target of 20% renewables by 2020. It is clear that solar thermal will be one of the big winners of this historic decision.

Our immediate goal now is a European wide obligation to use solar thermal and other renewable energy sources for heating in buildings. No building should be newly erected without having a heat supply based on renewables. Our vision is the 100% solar-heated building, in the long run even the 100% solar-air-conditioned building.

The binding 20% target for renewables in Europe has brought this vision a giant step closer: Policy makers will have to do whatever they can to help solar thermal gain a significant share of the heating market. And the realistic prospect of a solar thermal market of 100 million square meters per year by 2020 is beginning to attract new investors and to mobilise new suppliers. Together we will make our solar thermal vision come true.

The 3rd estec conference mirrors many of the exciting new developments. We will hear about the dynamic market development in many different countries, about how the Solar Keymark has effectively opened markets, about the status and future prospects of solar cooling technologies. Estec2007 is a conference by the industry for the industry. It offers you the chance to hear from top experts about the issues most relevant for our sector. And it is a good opportunity to meet and talk with colleagues from all over Europe and beyond.

I wish all of us an interesting and pleasant estec2007!



Gerhard Rabensteiner
ESTIF President

Hans-Martin Rüter

President of BSW-Solar
German Solar Industry Association

Dear participants to estec2007,

Solar thermal power is currently experiencing a significant upturn all over Europe, its importance in German and European politics has increased massively in the past two years. The European Parliament's Resolution from January 2006 on the EU Heat Directive, the EU Commission's Energy Package from January 2007, the Resolution by the European Council on the binding aim of achieving 20% renewable energies by 2020 and the government declaration from 26th April 2007 by the German Federal Environment Minister on the planned adoption of the Heat Act in Germany all go to show that solar thermal power is now seen as an important component for future heating solutions.

A dynamic industry sector needs an international meeting point for experts to exchange ideas about products, policies, techniques, technology and industry. The estec conference, now taking place for the third time in Freiburg/Germany, has without doubt developed into the world's most important meeting point for solar thermal power. The German Solar Industry Association is proud to make its contribution to the success of the conference.

We welcome all participants to estec2007 in Germany and look forward to a fruitful exchange of ideas and more. The combination of the world's largest solar power industry trade fair, Intersolar, and the subsequent conference provides visitors with a comprehensive overview of the extensive range of products and exciting innovations in solar thermal power and photovoltaics from providers all over the world.

We hope that you feel at home in Freiburg im Breisgau, in the south-west of Germany between the Black Forest to the east and the Vosges in France to the west and we look forward to an exciting exchange of ideas.

With sunny greetings,

Hans-Martin Rüter
President BSW-Solar

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Solar as a major source of heating: the vision of the European Solar Thermal Technology Platform (ESTTP)

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Introduction

In the coming years, our energy and heat supply will face a fundamental change. In a few decades' time, we will have to completely sever our ties from crude oil and natural gas as our main heating energy source up till now. The target of reducing CO2 emissions in industrial countries by 80% by the year 2050 can only be achieved if demand for low temperature heat is drastically reduced and the remaining demand for heat is completely covered by renewable energies. In the heating sector, this can be done without any problems and without any loss in comfort. The remaining crude oil and natural gas supplies will be used mainly in the transport industry.

The public's perception of energy problems has changed considerably since the last estec conference with regard to energy prices, reliability of supply and climate change. Crude oil prices increased almost eightfold from USD 10 per barrel in 1999 to USD 78 in August 2006 and have between fluctuating between USD 51 and 68 ever since. Many members of the public expect prices to rise further. Oil and gas supplies are being increasingly used as a political weapon. In January 2006, Russia's President Putin temporarily stopped the natural gas supplies to the Ukraine and in January 2007 the oil pipeline to Belarus, named "Drushba" ("Friendship"), was brought to a standstill. The supplies to Europe were only briefly interrupted in both cases but the events received a great deal of attention from the media and politics. Most of the crude oil and natural gas deposits that still exist are in politically unstable regions.

Climate change is marching on faster than was previously assumed. The film "An Inconvenient Truth" by Al Gore has sharpened awareness worldwide of the problem of climate change. The February 2007 publication of the IPCC report indicating that the climate change is caused by humans and the April 2007 IPCC report describing the drastic consequences for billions of people have found a strong echo and have triggered heavy discussion of the measures required.

When it comes to sustainable heating there aren't many options available. The necessary heat demand that remains after all potential efficiency measures have been called upon can be covered by biomass, geothermal heat with and without heat pumps, or solar thermal energy. The potential for biomass and geothermal energy are limited. Besides, both will also be needed for producing electricity and biomass will furthermore be required for fuel production. Solar thermal will inevitably come to play the biggest part in heat generation, mainly because it has shown the greatest potential among all the renewable energy sources.

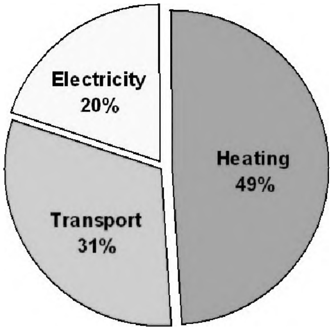


Fig. 1: Breakdown of final energy consumption in Europe

Today, about 49% of final energy demand in the EU25 is used for heating purposes. 80% of that demand is used for applications below 250°C. Most of this heat can be provided by solar thermal energy. These figures reflect the enormous potential for solar thermal as the main technology to replace traditional fuels used for heating and cooling.

The European Solar Thermal Technology Platform

Solar thermal currently only contributes just under 0.2% towards heat generation. In the long term it will have to be much higher than 50%. This can only be achieved if the share of solar thermal energy is greatly increased to between 50% and 100% per building and new areas of application are systematically tapped into, such as apartment buildings, hotels, tourism, commercial and industrial applications as well as solar cooling. It's true that, even today, there are many successful examples of solar thermal in all areas, but it is private housing that has dominated by far the extent of its use until now.

The European Solar Thermal Technology Platform (ESTTP) has set itself the target of systematically driving forward the further development in technology needed for this. In 2005, representatives from the solar thermal industry and research institutions got together. The European Commission had had the excellent idea of accelerating the development of future technology with technology platforms (TPs) and the representatives now also wanted to use this idea for solar thermal. On 31st May 2006, the foundation of the ESTTP ceremonially took place in Brussels in the presence of Energy Commissioner, Andris Piebalgs, who very much welcomed the Platform's foundation. The initiator group which was made up of representatives from ESTIF and the European Renewable Energy Research Centres Agency, EUREC, were able at this time to present an initial, provisional solar thermal vision for the year 2030 – this vision having been created by a great number of solar thermal experts from all over Europe.

In general, the technology platforms' task is to create a long-term technology vision and to draw up a corresponding Strategic Research Agenda based on this vision. Market introduction strategies are supposed to be described as well. Technology platforms (TPs) are organisations in which industry, research and political institutions work together and which are organised and managed by industry and researchers themselves. TPs are open to all interested parties and are meant to reflect as much of the whole sector as possible.

At a kick-off meeting on 6th December 2006, the ESTTP formed 12 working groups in three focus groups that each work on specific topics. It is their job to develop the detailed visions for 2030 in their respective areas and to propose the research activities needed. The ESTTP plans on presenting a new version of the solar thermal vision 2030 as well as an initial version of a Strategic Research Agenda at the beginning of 2008. The drafts of these documents will be discussed at a working conference in Brussels on 22nd and 23rd October 2007.

The main ideas of the existing Solar Thermal Vision for 2030 are described in the following:

Solar vision for new buildings: the Active Solar Building

The Active Solar Building will be completely heated by solar thermal energy. There are various ways to achieve the goal in Southern as well as in Central and Northern Europe. Active solar thermal energy systems could be integrated into the walls, thus efficiently minimising heating requirements whilst providing an active and efficient flow of heat energy into the building. In summer, the heat energy can be used for cooling, as required. Solar collectors on the roof will provide heat for domestic water. As an alternative to wall-integrated, active solar energy systems, large collector fields on the roof and in the facade can feed into seasonal compact heat storage systems that retain the energy for use in the winter months.

Active solar thermal energy systems can also be used for cooling the building. Systems will be adapted to accommodate geographic differences. Buildings in the north of Europe will concentrate more on the heating aspects, while buildings in the south of Europe will tend towards cooling. Buildings in Central Europe will most likely balance the two aspects in their generic approaches.

Solar vision for the existing building stock: Active Solar Renovation

Active solar renovated buildings will be heated and cooled by at least 50% with solar thermal energy and active solar renovation will be the most cost-efficient way to renovate buildings. In the future, the energy-related renovation of the existing building stock will be a much bigger task than the construction of new buildings. All throughout Europe, active solar thermal energy systems offer excellent options for carrying out the energy-related renovation of buildings. Huge synergy effects can be used by combining active solar thermal systems with insulation measures.

Active Solar Renovation could mean that compact facade or roof units containing active solar elements will be placed on top of existing facades for insulation and energy production purposes. Various solar facade and roof modules will be available, for example, solar thermal collectors for water or air heating, photovoltaic modules for electricity generation, as well as modules with transparent insulation for directly heating the walls. Facade elements used for the heat insulation of existing buildings will be significantly thinner and, at the same time, offer greatly improved insulation characteristics, for example, through the use of vacuum insulation. The elements will be offered in a wide range of standard grid sizes and will offer the architect countless alternatives for adding full-surface solar facades to the building.

Other facade elements could be directly coupled to the existing wall. The wall will be able to efficiently absorb solar energy and direct the heat into the building in a controlled manner. Layers within the wall will be able to regulate the heat flow into the building efficiently for heating the building in winter through the wall and insulating it against external heat outside the heating period. Buildings could be largely heated by the walls using this technique. In summer, the solar heat will be used for cooling the building. Cooling machines driven by solar heat will be much smaller than today's and highly integrated. As a result, the thermal comfort of the buildings will be much higher than today.

Block and district heating

In cities with dense building areas, block and district heating systems must significantly increase their share of heat from solar thermal energy, biomass and geothermal. By 2030, the use of fossil fuels will be replaced by renewable heating systems in existing block and district heating plants, e.g. in Sweden and Poland, where they are common. In other countries in Southern, Central and Northern Europe, new block and district heating systems will be built. Solar thermal energy will cover a large proportion of the energy demands of these block and district heating systems.

Solar assisted cooling

The world air-conditioning market is expected to grow exponentially in the next decades and the demand for building air-conditioning will definitely also increase in European and Mediterranean countries. Although intelligent architecture will significantly reduce the cooling loads, and the use of environmental heat sinks such as soil or air will save energy and cover some of the cooling requirements, the rising demand for comfort and increasing summer temperatures will still cause a rapid growth in space cooling loads.

Solar assisted cooling (SAC) machines will cover a large share of the cooling demand. Due to the simultaneity of cooling demand and solar radiation, solar assisted cooling technology is highly likely to cover a large share of the cooling demand. An important reason for using SAC is the need to avoid a totally unbalanced peak in electricity production during the summer period.

Solar thermal desalination

One of the most urgent global tasks to be solved in the future will be to supply people with clean drinking water. It is necessary to accelerate the development of innovative water production systems from renewable energy. Keeping in mind the climate protection targets and strong environmental concerns, water desalination and water treatment around the world will be increasingly powered by solar, wind and other clean natural resources in future.

Process heat for industrial needs and new applications

28% of the end energy demand in the EU25 countries originates in the industrial sector. Many industrial processes require heat on a temperature level below 250 °C. By 2030, solar thermal systems will be widely used to serve that market segment. Important areas for solar thermal systems exist in the food and drink industries, the textile and chemical industries and in washing processes. Factory and office buildings, shopping centres, etc. will also be heated and cooled using solar thermal energy in the future.

The availability of high-temperature collectors will lead to the development of other new solar thermal applications, e.g. solar thermal-driven refrigerators, steam-sterilisers, solar cookers or compact solar air-conditioning systems.

R & D Activities

There is a great potential for technological improvements in all components of solar thermal systems. Just a few of the ideas are described in the following:

Solar thermal collectors

- will cover the entire south-facing roof surface (orientation from east to west); together with photovoltaic modules, combined solar thermal and electricity collectors (PVT) will be available, south-facing facades will also be used as active solar absorption surfaces,
- will be completely integrated into building envelope components, a new synergy will occur through compact construction techniques and the intelligent multi-use of construction components,
- will be available for high-temperature applications as well as large-scale collector modules, facade-integrated modules and inexpensive low temperature collectors,
- will use new materials, e.g. a new generation of plastics, natural materials with super-insulating characteristics, ceramics, metal, foam and glass with dirt-resistant and IR-reflective layers or switchable layers which allow the performance of the solar thermal collector to be dynamically adjusted to suit immediate requirements by adjustment of the level of reflection and
- will contain improved selective absorber coatings regarding dirt resistance, high-temperature resistance, chemical resistance and performance regulation.

Heat stores

- will offer a significantly higher energy density and will reduce the required volume drastically; the goal is an eightfold increase in the energy density of storage compared to water as storage medium,
- will have greatly improved thermal insulation, e.g. using vacuum insulation,
- will be available as a seasonal heat storage system with a volume of only a few cubic metres for single family houses and
- will be integrated into the traditional construction elements of the building; a complete, decentralised solar thermal unit with solar collector in the facades, storage in the wall and layers which control the heat fluid is possible.

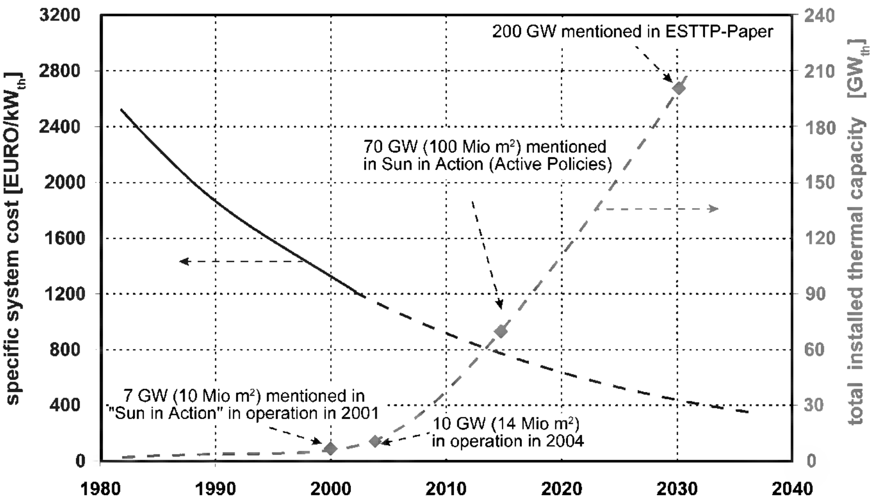
Further improvements will also be carried out in the other components of solar thermal systems such as

- heat transfer equipment
- controllers and monitoring components
- solar district heating technology
- very large seasonal stores
- thermally driven cooling systems

- solar sea water desalination and water treatment
- auxiliary systems

Cost reduction perspective

The learning curve of the costs for a typical DHW system in Central Europe indicates past cost development as a function of time and increasing installed capacity. The estimates as to further cost development are based on the typical learning curve theories, depending on the expected growth of installed capacity.



Development of specific costs and installed capacity for small solar thermal systems with forced circulation in Central Europe

Within 20 years, costs will be reduced by more than 50%. In Southern Europe, solar thermal energy is much cheaper due to higher solar radiation and lower costs for solar thermal systems. Therefore, in many Southern European regions, solar heat is already cost-competitive with heat produced by fossil fuels. Further cost reductions will depend on the development of the market and of the technology. Therefore, market entrance policy and R&D activities have to be continued or strengthened.

References

(1) Solar Thermal Vision 2030, first version, May 2006, www.esttp.org

Challenges and Opportunities at the edge of wide market introduction

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Introduction

Besides political leaders "trying to rule the world" and the continuous threat of terrorism, the supply of *Energy and Water* will be a major subjects in future. Looking at the very ambitious targets of ESTTP (European Solar Thermal Technology Platform) and STAP (Solar Thermal Action Plan) it looks as if we are heading towards a bright future for Solar Thermal. But are we – the industry – prepared for this? There is surely much room for further improvement of today's business and market approach to be able to take on this challenge! There is also still a certain lack regarding convincing long term strategies and early measurements – even for some big players it seems that the future scenario is not yet "imaginable".

The Solar Thermal Industry has done a great job so far but before we start to celebrate there is still some homework to be done. There are a few points which I would like to mention.

Energy demand and supply

Despite ongoing political talks, world summits, negotiations, promises and strong warnings (e.g. IPCC & Stern Reports) to reduce energy consumption the global *energy demand* will continue to grow over the next decades! It will actually double in the OECD countries and rise by about 20 % in developing countries. Only the transmission economies will have almost "stable energy demand" – at still low levels.

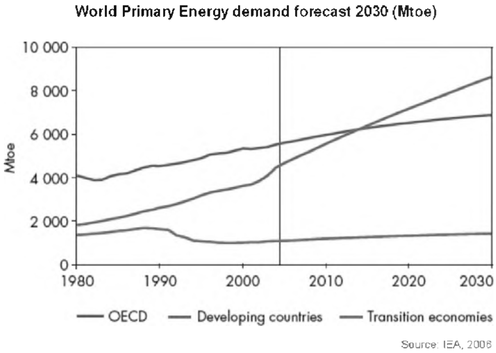

Fig. 1: The global energy demand will grow constantly over the next decades

Future *energy supply* will however change dramatically, as seen in the chart below. "Solar Power" will have the major contribution to future energy supply already by 2050, but even more obviously by 2100. Solar Thermal will have a large share in the following market segments:

- Domestic Hot Water Supply
- Space Heating
- Solar Cooling
- Industrial Process Heat
- Water Desalination

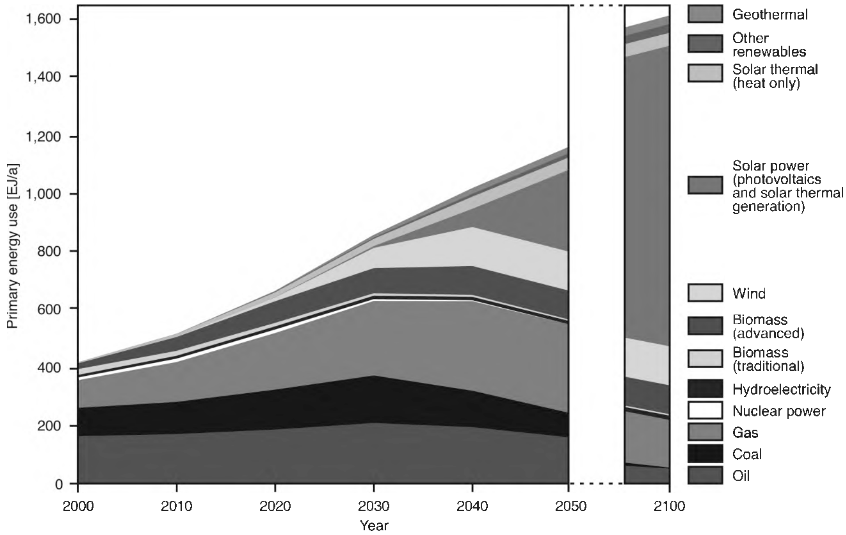

Fig. 2: Primary energy supply in future – Renewables will be the winner. Source: WBGU

Key benefits of Solar Thermal

Solar Thermal systems are based on simple principle: using the sun to heat water! Solar Thermal technologies which are on the market today are efficient and highly reliable, and provide solar energy solutions for a wide range of use. The key benefits are:

- Inexhaustible
- Reduces the dependency on imported fuels
- Saves CO_2 emissions at low costs
- Curbs urban air pollution
- Creates local jobs and stimulates the local economy
- Is a proven renewable energy source
- is immediately available – all over the world

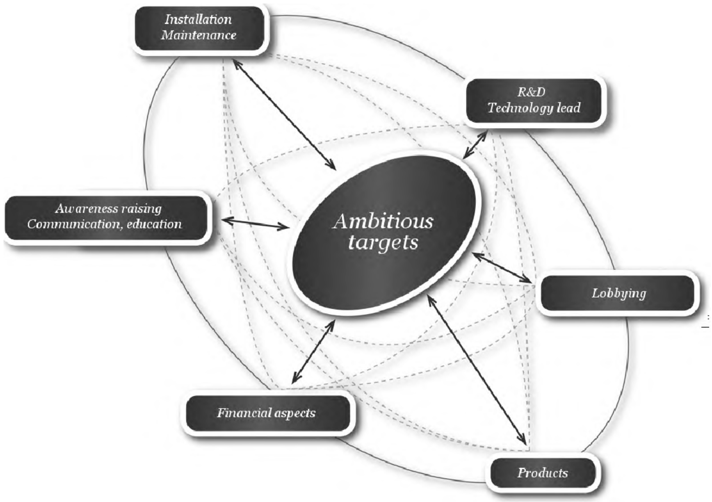

Fig. 3: Ambitious targets need ambitious strategies and measures

Financial aspects

In only 12 years from now the ambitious target of 460 million m² (320 GW_{th}) of "ST-System in operation" will be achieved! Is our industry able to master the immense expansion that we foresee and expect in the coming years and decades? How will this growth be financed? Will it mainly be growth from within or when do we see private equity firms entering Solar Thermal? And if so when are the first Solar Thermal companies going public? What about pro-active M & A negotiations among European players or even global alliances – rather than company takeovers.

For the expected future growth the Solar Thermal industry will need partners – both for strategic alliances and financial investors!

R & D and Technology lead

The European industry is today in many fields the technological leader in Solar Thermal worldwide! However with the European market being only a fraction of the Chinese one – will it stay like this? The ESTTP offers a platform to develop the future, to identify new products and markets. Still too few companies are accepting the chance the ESTTP offers. Obviously, not enough companies are thinking about the future.

Beyond market growth, maintaining the technological lead requires even more joint efforts to define and implement the research strategy which is required to meet the energy needs of tomorrow's world. Does the Solar Thermal industry spend enough time and money on R & D? *Certainly not!* When looking at the figures of the FVS (Forschungs-Verbund Solarenergie), the distribution of funds as well as the list of activities & projects in the various Research Institutes and compared with the very active PV industry.

Is the industry finally convinced to take the next steps to radically increase the market penetration of new applications such as SAC (Solar Assisted Cooling), IPH (Industrial Process Heat), Desalination and more cost efficient systems for block and district heating as well as heat contracting?

Furthermore there is a need for fundamental research in:

- Heat storage – a key technology/application for the future
- Medium temperature collectors and systems
- More cost efficient materials for collectors and storage
- Low cost collectors for façade integration – with long lifetime expectancy
- Combined PV-Solar Thermal systems
- Combined total energy systems

Products

As in all industrial sectors manufacturing will be more exposed to global competition as the market develops. European Solar Thermal products are usually good or even high quality, but low-cost producers – e.g. from China, Israel, Turkey (and certainly others to come) are trying to enter the EU markets. The Barcelona-Model for example suggests to customers (end consumer) to buy the "cheapest systems available" to fulfils the building regulation. How does the industry deal with this challenge?

Do we have the right products for global need in different applications under various (extreme) climate conditions?

Mass production must drive down costs for Solar Thermal systems – along the whole value chain – to be able to compete and deliver!

Installation & Maintenance

One of the goals in the STAP is that "every installer offers Solar Thermal systems". But can all of them install and maintain the system properly? Today – Certainly not!

The focus of manufacturers and installers today is on selling their products/systems. Although most of the manufacturers have already implemented training courses over the past years, there is still a need for improved education and instruction during the apprenticeship – Solar Thermal must be integrated in general training courses for apprentices!

Training and education are the key factors in achieving a wider adoption of Solar Thermal energy. Usually the standard training of apprentices does not include Solar Thermal technology. At the same time lack of training and experience can lead to poor installations, thus creating avoidable quality problems and decreasing the acceptance of Solar Thermal! How do we want to prevent untrained and unmotivated installers from installing at a medium to poor quality level? It is clearly the obligation of the Solar Thermal industry to educate & train them!

Otherwise how do we prevent a possible backlash as we have seen in some countries in the 1980s – without erecting unnecessary new barriers of acceptance?

Very low priority is given to the maintenance of already installed Solar Thermal systems – a fact that in my opinion is a latent problem and needs far more attention so as not to become a "must" in future. Maintenance requirements are obviously only small but maintenance costs are not really known. "Everyone believes it's not very much" but no-one in the industry can put a figure to it! Why don't we implement a proper professional ASSS (After Sales Solar Service) e.g. issuing a "Guaranty Pass" with a mandatory annual or bi-annual quality check, as it is common practise for normal heating system – which is fully accepted!

To effectively implement maintenance schedules, we however need to know the performance of the Solar Thermal system first i.e. having a metering system measuring the output in kWh – only what can be measured can be promised! In this respect we still "think in area (m^2) or systems (No.) instead of energy output" (energy production in kWh).

Of course it is slightly more difficult than with PV-systems but it is not impossible either – it simply needs to be installed with every Solar Thermal system! Otherwise how would governments possibly react when the predicted market growth becomes a reality but the energy savings (performance) stay behind?

We need something like a GSR (Guaranteed Solar Result) for Solar Thermal systems. Nothing new actually – as it has already been implemented in part in Spain and France.

The widely accepted and introduces Quality System "Solar Keymark" is already a good basis for this – on our way towards "fully controlled Solar Thermal systems"!

Besides that, the implementation of such a service could also create a significant number of new jobs when we achieve our 2020 target of 1 m² of collector per European. We will have ~24 million systems in operation, when calculating at 460 million m² in operation with an average system size of ~20 m². We will need about 15,000 full-time persons to do the job, if each system only needs 1 hour of maintenance per year! Is that not a good challenge and an excellent opportunity?

Awareness and communication

The industry but mainly the Associations – with the support of government bodies – have done an excellent job in the past with the various successful awareness raising campaigns. However those activities not only need to be continued but need to be increased further. Only a fraction of people in European (end consumers) are sufficiently informed about the possibilities, applications and the great potential of Solar Thermal.

A decisive role in the market is also played by professionals groups such as architects, planners and installers who are the interface between end consumers and the industry. These professionals often determine or have strong influence on the end consumer's or developer's choice about heating systems. Most of them are not even well enough informed. For this reason many of these professionals do not feel comfortable recommending Solar Thermal or even discourage its use to avoid having to plan and deal with a technology "unknown to them"!

"Solar Power" is a major source in future energy supply and Renewable Energy in general must become an integral element and a part of standard information in education! Professionals from the industry and research institutes as well as from associations could initiate a program such as "train the trainers" and act as part-time lecturers.

Lobbying

The Solar Associations in the EU have so far done a great job in professional political Lobbying – but still lacks sufficient support from the industry. Today there is a much higher level of awareness on EU and national level compared to a few years ago – when "Solar Power" was mainly regarded as only PV!

Solar Thermal and its potential are not only well-known to decision makers but Solar Thermal also plays a decisive role in EU energy policy matters today and in future.

However – compared to the PV-Industry – there is much room left for improvement. I would therefore like to see significantly more commitment and active personal involvement of the "big players" in the EU and especially in Germany, also at top-management level, to build-up and strengthen our relationships with political leaders!

Conclusion

Either the Solar Thermal Industry takes up the challenge and actively creates its own future – or will miss the historic chance and continue to do business by opportunity.

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Solar Heat for Industrial Processes. Existing Plants and Potential for Future Applications

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Introduction

Considering the new and interesting applications for the solar thermal technologies, the industrial process heat at low and medium temperature up to 250 °C is one of the most promising. Industrial sectors such as food, wine and beverage, textile, transport equipment (e.g. car washing), pulp and paper, surface metal treatment (e.g. galvanic) and to a lesser extent the chemical require process heat in this temperature range. The areas of application are numerous and include different processes such as cooking, boiling, drying, dying and cleaning. In addition, several built examples showed that space heating of factory buildings has to be considered one of the most promising applications of solar thermal in industry.

A survey on the existing solar thermal plants for industrial process heat and a review of the potential studies for future applications have been performed in the framework of the IEA Solar Heating and Cooling Programme and SolarPaces Task 33/IV: the preliminary results are summarised in the present paper.

Solar industrial process heat plants in operation

Data gathered in the framework of the IEA Task 33/IV – Solar Heat for Industrial Processes (SHIP) include comprehensive information about the geographical distribution of the solar thermal plants, the industrial sectors addressed (e.g. food, textile, etc.), the specific processes (e.g. washing, drying, etc.), the process temperatures, the solar thermal collectors technology, the capacity installed, the type of back-up systems and some economics.

This survey include the majority of the worldwide built examples with few exceptions such as China and Japan.

Applications, systems and technologies included in the scope of this survey are:

- All industrial processes where heat up to a temperature of 250 °C is needed;
- Space heating of factory buildings;
- Solar thermal systems using air, water, low pressure steam or oil as heat carrier;

– All types of solar thermal collectors working up to 250 °C: unglazed collectors, flat-plate collectors, improved flat-plate collectors, evacuated tube collectors with or without reflectors, CPC collectors and parabolic trough collectors.

Specific applications such as desalination, space cooling and refrigeration were not the main focus of the survey. Nevertheless they have been reported as they might be considered of big interest for future SHIP installations.

Currently about 86 solar thermal plants for process heat have been reported worldwide with a total installed capacity of about 24 MW_{th} (34,000 m²).

At the present time data collection comprises 19 countries. Plants in operation in Austria, Greece, Spain, Germany, Italy and the USA represent about 75% of the total installed capacity reported. The US plants alone contribute for 42% with 10 MW_{th} (8 plants) in operation. It follows Greece with about 4.4 MW_{th} (10 plants), Spain with about 1.4 MW_{th} (10 plants) and Austria with the highest number of examples: 21 plants installed.

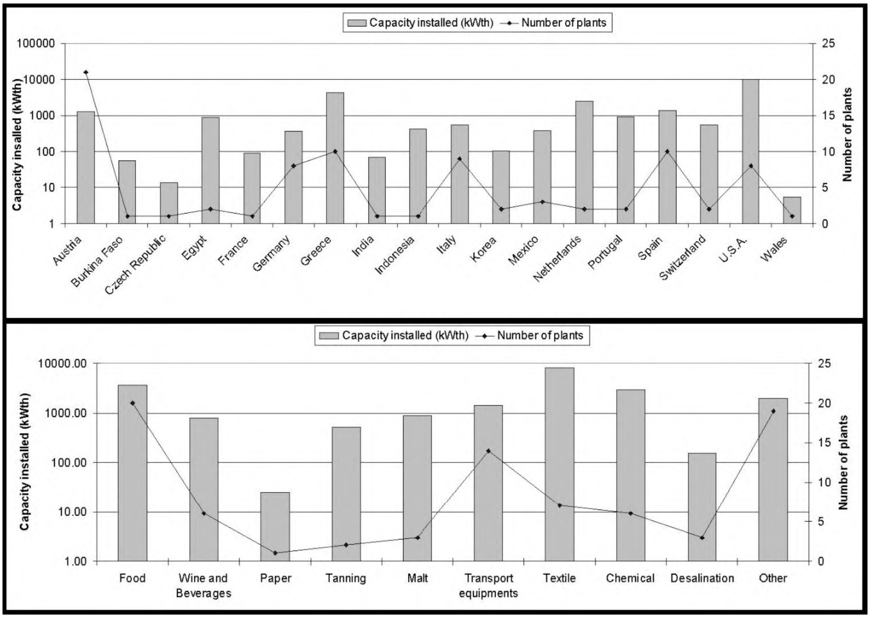

Fig. 1: Solar industrial process heat plants in operation. Installed capacity and number of plants: distribution by country and by industrial sector

The size of SHIP plants varies from small (around 10 kW_{th}) to large scale installations over 800 kW_{th}. The census revealed no significant correlation among the plant size and other relevant parameters such as the type of industrial application or the process temperature range. On the other hand, the geographical distribution of collected examples shows that the largest plants are almost all located in USA while, at EU level, the average size of the SHIP plants installed in Austria, Italy and Germany is around 50 kW_{th}. Greek installations range from medium size up to 1,890 kW_{th} (i.e. Sarantis, solar cooling), while the largest plant recorded up to now in Spain is Contank, around 357 kW_{th}.

The majority of the SHIP plants operate in the sectors of food, wine and beverages, car washing facilities, metal treatments, textile and the chemical industries. Examples in food processing sectors (especially dairies) are particularly numerous: i.e. 20 plants corresponding to 23% of the sample. Wineries account for 4 of the 8 examples reported within the beverages sector, showing a large potential for future applications especially bottle washing and cooling of wine cellars. Breweries require huge amounts of low and medium temperature heat and therefore this sector should be further investigated. A first step was moved in the framework of the IEA task33/IV and a new sun-brewery has been built in Austria, and it is now successfully running.

Solar car washing facilities are concentrated in Germany and Austria (8 examples), while dairies in Greece and in Italy (6 examples). 10 solar façade integrated systems are in operation in Austria for space heating of factory buildings, while in Spain the most recent solar thermal applications are mainly in the food (e.g. olives, meat and fish processing) and transport equipment sectors (e.g. washing facilities for lorries and containers).

Fig. 2: Solar industrial process heat plant for a brewery in Austria (Source: AEE Intec)

If we look at the installed capacity the textile sector, including tanning, accounts for the highest share (36%, about 8.6 MW_{th} installed) while, e.g., the 14 plants in the transport sector cover not more than 6% (about 1.4 MW_{th}) due to the smaller average plant size.

About 60 industrial solar plants supply heat at temperatures below 100 °C. The solar thermal system usually includes a storage, required for discontinuous manufacturing activities with week-end breaks or for batch processes. Solar heat is mainly used at 20–90 °C for process hot water, preheating of boiler feed-water and space heating (and cooling).

Therefore standard selective flat plate collectors (FPC), working in the temperature range of 30–90 °C, result to be the most installed (11 MW_{th}) and parabolic trough collectors (PTC) are also relevant in terms of capacity installed (3.5 MW_{th}). For economic reasons (usually one tracking unit is used for several collector rows), the plant size in fact should not be too small.

PTCs for process heat are mainly installed in USA: few built examples are also in Israel, Mexico, Egypt and India, but at present no detailed information are available.

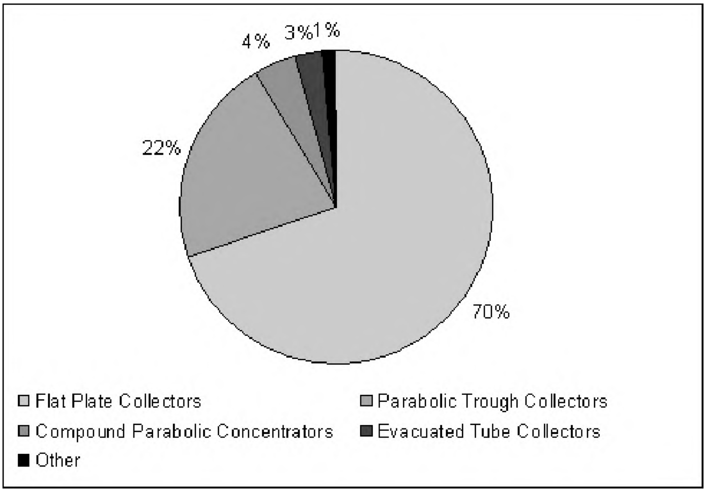

Fig. 3: Share of installed capacity by collector technology. The share is calculated on a total capacity of 16.5 MW_{th}

5 evacuated tube collectors (ETC) plants are in operation for producing process hot water while 4 for space heating and cooling.

Cost figures, available for about 50% of the plants analysed, range from 450 to 1,100 €/kW_{th} with few exceptions and some differences at national level.

Costs are related to FPC and ETC plants only. In Austria and Spain, the investment cost (plant size < 350 kW_{th}) is in the range between 470 and 700 €/kW_{th}, while costs collected for Germany and Italy in average are higher. Costs for Greek plants are lower because of some targeted marketing strategies adopted in the 90ies by the solar thermal companies. Due to a lack of detailed information in most of the cases it was not possible to identify all the items included in the investment costs declared and to clearly define the operating conditions; therefore figures showed in Table 1 are not fully comparable.

Country	Year of installation	Collectors type	Installed capaciy (kWth)	Cost (€/kWth)	Co-funding
Austria	1994	FPC	62	470,78	20%
	2001	FPC	29	680,27	30%
	2002	FPC	30	498,34	30%
	2004	FPC	36	961,54	30%
Germany	1996	FPC	17	803,57	20%
	1998	FPC	106	1062,44	55%
	1998	ETC	18	960,00	n.a.
Greece	1993	FPC	119	217,65	50%
	1999	FPC	1890	691,01	50%
	2000	FPC	518	254,83	50%
	2000	FPC	509	353,70	n.a.
	2001	FPC	706	247,77	50%
Italy	2003	FPC	78	745,26	n.a.
	2004	FPC	101	1038,78	n.a.
	2004	FPC	188	584,17	40%
	2005	ETC	47	1097,60	none
	2005	FPC	40	952,38	30%
	2005	FPC	10	1240,08	30%
Portugal	1992	FPC	462	445,35	49%
Spain	1994	FPC	97	662,53	63%
	1997	FPC	182	541,76	49%
	2002	FPC	106	638,60	44%
	2004	FPC	357	752,23	48%

Table 1: Investment costs per kW_{th} for some solar industrial process heat plants in operation.

Most of the reported plants benefited of public contributions between 30% and 50% of the total cost.

POTENTIAL FOR FUTURE APPLICATIONS

Looking at this new promising market, several studies on the potential for solar industrial process heat have been recently performed in different countries such as Austria, Spain, Portugal, Italy and Netherlands. The review on potential studies, on going in the framework of IEA Task33/IV, comprises also analyses at regional level (Wallonia region and Victoria state, while a new study is on going for Stiria) and for specific industrial sectors (Greece and Germany). study

Different methodological approaches were used within the studies surveyed. For Spain and Portugal [2], for instance, a bottom – up approach was adopted and the results of 34 detailed case studies have been extended to the overall industrial sector. On the other hand, a top-down approach were used for Austria in Promise [1] where some case studies have been used to validate the outcomes of the calculations based on theoretical assumptions. Within the preliminary phase of those studies, the most relevant industrial sectors have been identified and the heat demand at low and medium temperature assessed.

As matter of fact national and international statistics show a lack of information concerning the industrial heat demand and its share by working temperature. A recent survey estimates that 30% of the total industrial heat demand in 32 countries (including EU25) needs temperatures below 100 °C (about 70% up to 400 °C) [8], almost in line with the results of the solar process heat potential studies. In several industrial sectors, such as food industry, wine and beverage, transport equipment, machinery, textile and pulp and paper, the heat demand at low and medium temperature is about (and even above) 60% of the total heat demand [8,2]. Additionally, it has to be remarked that very often industrial processes are considered as medium temperature heat users even though operations would require thermal energy at low temperature because the working temperature needed in the process is confused with the higher temperature of the heat carrier (most of the time steam, even when not strictly required).

Knowing the heat demand of relevant industry sectors, the following step foresees the evaluation of the technical potential: all the cases where the integration of a solar thermal plant is assumed to be technically feasible have been included. Experiences show that the available roof or ground area for installation is one of the most limiting factor.

Finally, decisive factors for the economical potential are the energy costs of fossil fuels, especially low for big industrial companies, and of other competing technologies (e.g. heat recovery). At the present time there are applications where solar thermal process heat is cost competitive with traditional energy sources. However, some form of economic assistance would reduce payback periods, often still beyond industry targets, and encourage the takeoff.

It follows that several factors are of great importance for solar process heat, such as:

- Type of process (batch, continuous) and the temperature of usage;
- Availability of process intrinsic heat storages;
- Possibilities of coupling solar with available industrial equipments (e.g. heat exchangers, machineries etc.) and of connection with the conventional heat supply systems;

- Opportunities for heat recovery from high temperature processes;
- Availability of roof or ground area for installation;
- Costs and funding opportunities.

Concerning the results obtained, the studies on future solar process heat applications show a large potential. Even though not fully comparable because of the different methodologies adopted, the solar potential estimated for Austria is 4.4 PJ [1], while for Iberian Peninsula (Spain and Portugal) and for Italy it reaches 21 PJ [2] and 32 PJ [5] respectively.

The potential surveyed for Netherlands give a lower potential (less than 2 PJ [6]) but, apart from the local conditions, it is also due to the fact that only process hot water up to 60 °C in twelve industry branches was taken into account.

A preliminary comparison between the solar potential estimated and the energy statistics as reported in Eurostat (year 2002) showed that solar thermal might provide industries with 2–3% of their final heat consumption in Austria, Spain, Portugal and Italy.

Extrapolating this result to EU 25, the contribution of solar process heat might be 64 TWh per annum (230 PJ/a), with an installed capacity of about 100 GW_{th} assuming an average solar energy yield of 450 kWh/m^2.

Conclusion

In the last few years the number of solar thermal plants for industrial applications at low and medium temperature almost doubled.

In several studies on solar thermal energy in industry, a very large application potential has been highlighted.

Among the most promising industrial sectors food industry, wine and beverage, transport equipment, textile, pulp and paper and part of chemical show the biggest potential for future applications.

Estimating a potential of 2–3% of the industrial final heat consumption it would lead to an market volume of about 100 GW_{th} of new capacity installed (>140,000,000 m^2) for the European solar industry.

Solar thermal should help to reach the recently established EU target of 20% renewables share by 2020. In order to have a relevant contribution, not only the conventional application are needed, but also these relatively innovative solutions with their high and so far unexploited potential. Provide economic incentives and support further R&D would help to reduce payback – time for applications close to being viable and to improve the maturity of technologies for medium temperatures.

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Industrial Process Heat in Practice: Challenges in Dealing With Real Life Situations

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The Potential of Solar Process Heat

The industrial sector represents the highest energy use in OECD countries at about 30%, closely followed by the transport sector. Due to the fact that energy from fossil fuels was for a long time cheap and seemingly infinitely available, manufacturing companies have only taken modest steps towards replacing energy from fossil fuels with energy from renewable sources.

The use of solar energy in manufacturing and industrial processes and to heat factory buildings has been limited to just a few applications. Solar thermal collectors installed today have a total thermal capacity of around 118 GW_{th}, but are used almost exclusively for domestic hot water, swimming pools and space heating in the residential and tourism sectors /1/.

Recognizing the importance of this sector, the IEA SHC Programme and the IEA SolarPACES Programme are working collaboratively. The expertise from eight countries represented by 16 institutes and 11 companies have joined together to work in SHC Task 33/IV 'Solar Heat for Industrial Processes'. The participants collaborate to provide a comprehensive description of the potential and the state-of-the-art applications of solar heat for industrial process; to disseminate the knowledge gained to solar manufacturers, process engineers, installers and potential buyers (industry); to identify applications and the corresponding temperature levels of the processes suitable for solar energy; to develop, improve and optimise collectors, components and systems with a temperature level up to 250 °C; and to initiate pilot projects covering a broad range of technologies to become a 'best practice'.

One of the first objectives of Task 33/IV was to investigate the potential of solar process heat, to document existing plants and to analyse the experiences from these plants.

Studies on the potential of solar heat for industrial processes at low temperatures conducted in Austria, Portugal and Spain show that solar heat could provide approximately 26 PJ /2/. If only 5% of this (technically feasible) potential were to be achieved in the coming years this would require the installation of one million square meters of collectors with a capacity of 700 MW_{th}.

To be able to make use of the huge potential for solar heat in the industry and to open a new market sector for the solar thermal industry, it is necessary to develop system concepts that integrate solar thermal systems into the individual industrial processes in a suitable way.

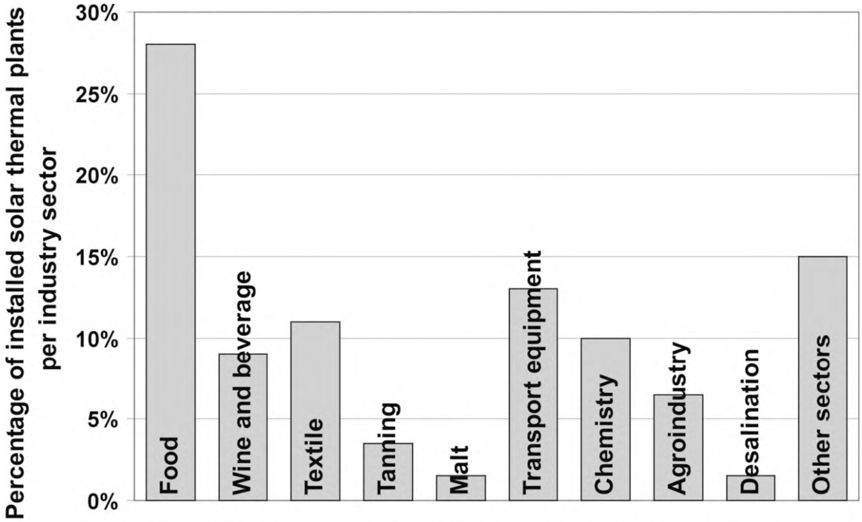

Fig. 1: Distribution of documented solar thermal plants in different industrial sectors

The current situation

About 85 solar thermal plants for process heat are reported worldwide, with a total installed capacity of about 27 MW_{th} (38,500 m²), see Fig. 1. Table 1 shows the temperatures which are required for certain processes in different industrial sectors up to a temperature level of around 250 °C. The industrial sectors that need a lot of heat in this temperature range, are the food and beverage industries, the textile and chemical industries and for simple cleaning processes, e.g. car washes. Between 30 °C and 90 °C, flat-plate collectors work very efficiently.

To be able to provide heat for the entire medium-temperature range from 80 °C to 250 °C at a reasonable price, it is necessary to optimise and further develop medium temperature collectors. Therefore, three categories of medium-temperature collectors are being developed and tested as part of SHC Task 33.

Industrial sector	Process	Temperature level [°C]
Food and beverages	drying washing pasteurising boiling sterilising heat treatment	30 – 90 40 – 80 80 – 110 95 – 105 140 – 150 40 – 60
Textile industry	washing bleaching dyeing	40 –80 60 – 100 100 – 160
Chemical industry	boiling distilling various chemical processes	95 – 105 110 – 300 120 – 180
All sectors	pre-heating of boiler feed water heating of industrial buildings	30 – 100 30 – 80

Table 1: Industrial sectors and processes with the greatest potential for solar thermal uses

Development of Medium Temperature Collectors

Improved Flat-Plate Collectors

There is a number of different possibilities for developing flat-plate collectors that could be used in applications between 80 °C and 120 °C. In the first instance, it is necessary to reduce the thermal losses of the collectors without losing too much optical efficiency. This can be achieved, for example, by using flat-plate collectors with multiple anti-reflective glazing, or using a hermetically sealed flat-plate design where the collector is filled with a noble gas, or by the development of evacuated flat-plate collector designs. In the operating range between 80 °C and 120 °C, the collector efficiency can be improved compared to a standard flat plate collector by up to 15 percentage points.

Low Concentrating Collectors

A further possibility for the development of medium temperature collectors is to reduce thermal losses in the collector by concentrating the solar radiation and therefore reducing the surface area for heat losses. Compound parabolic concentrating (CPC) collectors, based on this principal, are being developed in Portugal by AoSol and INETI and in Austria by Solarfocus. For concentration factors up to around 2 there is no need for sun-tracking devices.

Small Parabolic Trough Collectors

For collector circuit temperatures of 150 °C to 250 °C, it is interesting to consider higher concentrating collectors. However, these can no longer be mounted in a fixed position but require a one-axis tracking mechanism. At present, seven concentrating collectors are under development within the framework of SHC Task 33. Further information on these developments can be found in the brochure 'Medium Temperature Collectors' available on the internet at www.iea-ship.org/3_1html.

Fig. 2: Testing a small parabolic trough collector at AEE INTEC

Integrating Solar Heat & Industrial Processes

There are several challenges to address before solar can be fully integrated in industrial processes. In using solar thermal energy, the temperature of the available heat and the variability of solar energy must be considered, as well as the heat profile required by the industrial process. Solar plants used to produce process heat can easily achieve a capacity of several hundred kilowatts up to several megawatts, but system technology is needed to be able to handle down time at a plant, for example on weekends and during holidays.

To address these challenges, more than 20 system concepts were developed according to the requirements of the different energy carriers (air, water-glycol, pressurised water or steam), the temperature levels and the process to be supplied with heat. These concepts are currently being realised and tested at demonstration plants.

Demonstration Plants

Factory Buildings

In contrast to other buildings, such as offices and apartments, factory buildings are very tall – 5 to 10 meters – and usually require a relatively low room temperature between 15–18 °C. The combination of lower temperatures and simple heating systems are ideal conditions for the use of solar thermal energy, and open up a significant potential use in the industrial sector.

In recent years, many industrial spaces have been built, particularly in Austria, which are heated completely or partially using solar energy. All of the documented spaces use underfloor heating systems to introduce heat to the space, and thereby giving the advantage of a low flow temperature and that the mass of the foundation can be used as a heat reservoir. The solar collectors are often mounted on or integrated in the facade. In this design, the collectors fulfil multiple functions simultaneously as a weatherproof facade, energy converter and as insulation (due to the rear insulation of the collector). Since the solar collectors are generally used for heating purposes, as the hot water requirements are usually small, the facade collectors are well oriented towards the winter sun.

The capacity installed on the documented industrial buildings is between 60 kW_{th}–150 kW_{th}. The solar fraction of total energy supplied ranges from 20% to 100%.

Washing Processes

Cleaning processes are used in particular in the food and textile industry and in the transport sector. For cleaning purposes, hot water is needed at a temperature between 40 °C and 90 °C and therefore flat-plate collectors can be used. In these systems, cold water is heated to the desired temperature and drained after usage. In most cases, heat recovery is not feasible. Therefore, the system design is quite similar to large-scale hot water systems for residential.

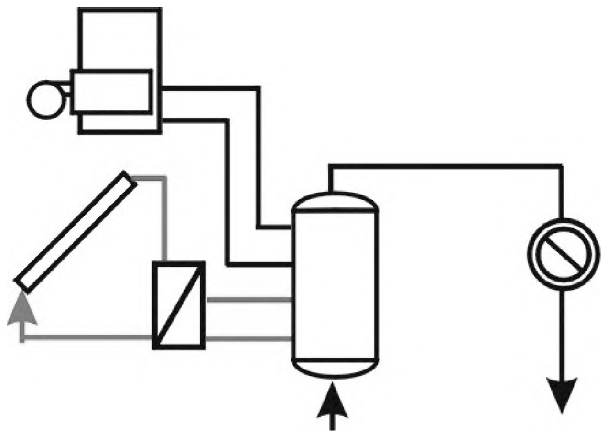

Fig. 3: Generic system concept for a washing processes using an open hot water loop

The company Contank (Parking Service Castellbisbal S. A.) in Barcelona, Spain cleans containers used to transport liquid goods by rail. The major heat-consuming process in the company is the washing process, which uses hot water at 70–80 °C (representing about 46% of the total heat requirement) and steam (representing 54%). The company requires 70–80 m³/day of hot water.

The solar thermal system installed at Contank consists of two solar fields with selective flat-plate collectors and a total installed heat capacity of 360 kW_{th} (510 m²) and a 40 m³ unpressurized storage tank. The yearly net solar energy yield is 429 MWh (588 kWh/kW_{th}), which corresponds to 21.6% of all energy used. If the gas price is assumed to be 25 €/MWh, this results in annual savings of 14,300 €. Taking into account maintenance costs, amortization is achieved in approximately 10 years.

Dairies

Another good example are dairies. The capacities of solar thermal plants in this sector are in the order of 1 to 10 MW_{th}. The solar thermal plant at the Tyras dairy in Trikala, Greece has an installed capacity of 730 kW_{th} (1040 m²). The average annual solar energy yield of the plant is 700 MWh, corresponding to 7% of the total heat requirement.

The total investment for the plant was 172,500 €, which is equivalent to 116 €/kW_{th} of installed capacity. Thanks to subsidies, which covered 50% of the costs, a short amortization time required by the industrial sector was achieved.

Distilling and Chemical Processes

For industrial processes where temperatures between 120–250 °C are needed, concentrating solar collectors, such as parabolic trough collectors or Fresnel collectors have to be used. The heat carrier in these systems can be either pressurized hot water or steam.

The Egyptian New & Renewable Energy Authority (NREA) issued an international tender to build a 1.3 t/hr pilot solar steam plant using parabolic trough collectors at a site just outside Cairo. The project, financed by the African Development Bank, has 144 parabolic concentrators arranged in four parallel rows that provide a net reflective area of 1,900 m². The steam is produced by pressure reduction of the water in the collector loop using a flashing valve and is delivered to an existing saturated steam network operating at 7.5 bar.

Conclusion

The major share of the energy that is needed in commercial and industrial companies for production processes and for heating factory buildings is below 250 °C. The industrial sectors with the greatest potential for solar thermal applications are the food, textile and chemical industry where processes such as drying, washing, sterilizing, dying, distilling and pre-heating of boiler feed water can be supplied with solar energy. In addition, space heating of industrial buildings is a suitable application.

Fig. 4: The El NASR Pharmaceutical Chemicals facility in Egypt has an installed capacity of 1.33 MW_{th}. Source: Fichtner Solar GmbH. Germany

The low temperature level (< 80 °C) complies with the temperature level that can easily be reached with solar thermal collectors already on the market. For the medium temperature processes, new collector designs are under development.

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Further information

www.iea-shc.org and www.iea-ship.org

Solar thermal desalination for remote areas – from research to market introduction

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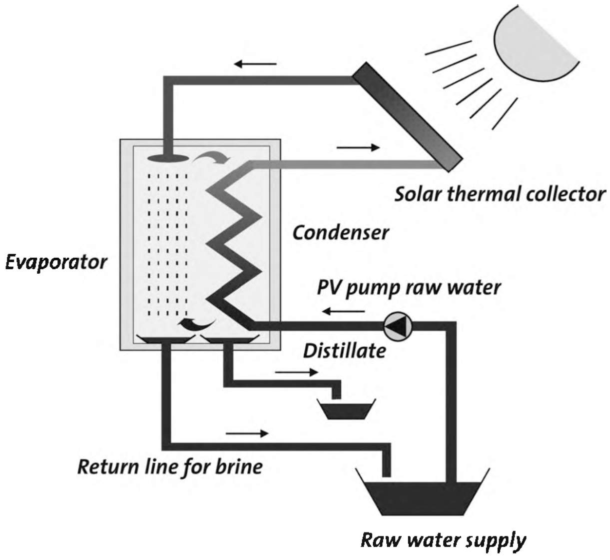
Introduction

Solar driven desalination systems based on evaporation of sea water and subsequent condensation of the generated steam have been investigated worldwide for many years. Starting from simple but sophisticated solar stills working very reliable and self sufficient on small scale drinking water production in the range up to some few hundred liters per day, improved concepts with increased solar desalination capacity had been realized mainly at a research level up to now.



The main tasks in terms of efficiency and economic improvements of the Solar Still concept were reduction of specific energy consumption and solar aperture area per cubic meter of water produced daily. One of the concepts for achieving this task is the Multiple Effect Humidification (MEH) method. A closed casing comprising heat and mass transfer is separated from solar collectors for heat supply of the process.

Evaporation and condensation surfaces are oriented in optimized configuration parallel to each other. This enables continuous temperature stratification along the heat and mass transfer surfaces, resulting in just a small temperature difference requested for keeping the process running. This is possible because most of the energy afforded in the evaporator is regained in the condenser, keeping the energy demand on a very low level of less than 90 kWh/m^3. Such systems have been available as industrial product since November 2005. Demonstration systems have been installed and commissioned in Jeddah/Kingdom of Saudi-Arabia. TiNOX now initiates the market introduction of solar desalination systems for the capacity range of between one and 50 m^3 per day.

Experience from pilot installations over more than 10 years

Former conceptual improvements in design and operation strategy had been verified in several research projects performed by the University of Munich and the Bavarian Center for Applied Energy Research (ZAE Bayern) from 1994 up to 2003. A first installation supplying fresh water from a beach well to a holiday resort started from 1994 on the west coast of Fuerteventura. This system was operated without using heat storage and was supplied by 4.2 m^2 tubular and 3.8 m^2 flat plate collector field, supplying about 0.2 m^3 of fresh water per day. The system was monitored regarding energy and water balances and the long term experience with materials is based on trial modifications at this plant.

Modified systems based on the experience from these days were installed in Sfax/Tunisia (Partners: TAS GmbH, Verein für solare Meerwasserentsalzung and Ecole Nationale d'Ingénieurs de Sfax), in Gran Canaria (CIEA/ITC) und Fraunhofer ISE; Solar collectors by Fraunhofer ISE Freiburg Germany (funded by the European commission) and in Muscat/Sultanate of Oman (Thermosolar and Sultan Qaboos University of Muscat, funded by the Middle East Desalination Research Center, MEDRC).

Bringing solar desalination systems into the market

Cost reduction by use of standardized componets

Top task when considering series production is efficient design and standardization of components. Reasonably as many ordinary available parts as possible should be used for cost effective production. In the present case, incorporation of transport casing and device containment was an essential step towards cost reduction. A standard 20 -CSC-container ensuring low freight rates during international transporttation is modified to carry the main components condenser and evaporator. An inside thermal isolation ensures optimum thermodynamic results. All parts needed for operation of the system such as pumps, valves, controllers are included in a small cabin implemented in the containment. Thus, the container is ready for operation as it comes out from production and may be quickly connected and put into operation at the respective locations.

Corrosion free materials ensure long life time

Material selection is one main aspect of cost reduction potential even previous to personal costs. Durability and functionality versus costs is the balance to be kept. Thus, all parts in contact with the brine are made from polypropylene or highly-alloyed stainless steel. The complete casing is vapour tight and lined with stainless steel. Heat and mass exchange surfaces are made from specially temperature treated and heat conduction enhanced polypropylene.

Those performance enhanced condenser plates are aggregated applying a time optimized extrusion welding method to stacks of condensation units.

High effort was set on the long term durability of the installation. Based on improvements learned from the former experiences with the pilot installations, twenty years life time can be expected, ensuring reasonable water prices and low maintenance demand during operation.

Demonstration systems operating in Jeddah/Saudi Arabia

First commercial desalination systems are presently set up in Arabian countries, first operating demonstration systems have been set up in Jeddah/Kingdom of Saudi Arabia in November 2005 and June 2006. These systems comprise a MidiSal™ unit with designed daily fresh water capacity of 5 m^3 and is supplied by a 140 m^2 solar thermal collector field and a 10 m³ heat storage tank ensuring 24 hours per day water production at solar driven operation:

Cost analysis of small scale desalination processes

Decentralized fresh water supply is a matter of different responsibilities underlying different influences. These are mainly water extraction, treatment, storage and distribution. In the case of desalination, the balance between investment and operational costs is one of the main aspects for fundamental decisions regarding two possible strategies to minimize lifetime water costs: low investment or low operational costs.

For middle scale installations (water production capacities from 5000 up to more than 10000 m³ per day), the fraction of initial investment on specific life time water costs is relatively low compared to small scale installations. At present it is reported to be in the range of between 0.2 and 0.5€ per m³ depending on the local conditions and the method applied. The costs of water distribution and costs due to leakages in the distribution grid are rarely monitored. Such costs vary between 0.1 € and 0.8 €/m³ with respect to local conditions. Operational costs due to energy consumption, chemical additives dosing, maintenance and spare parts are in the range of 0.2 €/m³ to 0.7 €/m³. All of this sums up to life time water costs for mid-range installations of between 0.5 €/m³ and 2 €/m³. These are the costs for installations in middle size towns, for larger holiday resorts comprising several hotels and island installations.

For mid scale installations in the range from 500 up to 5000 m³ per day, water costs of between 0.7 and 3.1 €/m³ are reported. Small installations of capacities from between 5 up to some 100 m³ per day are currently mainly served by small Reverse Osmosis (RO) installations. Due to local conditions, plants of this size are mainly operated by brackish water with salinities of between 2000 and 8000 ppm TDS. As reverse osmosis is highly sensitive to salt content with respect to membrane retain factor and pressures applied, the investment costs are extremely dependent on the raw water source. In the case of sea water, the investment cost share for the desalination system is between 0.5 and 1.4 €/m³. Operation and maintenance are the significant cost fraction at installations of this size. Regarding sea water RO, maintenance companies report on maintenance and energy costs between 0.9 and 2.8 €/m³ including labour costs. Thus, the resulting water prices range from 1.4 €/m³ up to 4.2 €/m³. The main aspect and advantage of the presented decentralized installation is its low maintenance demand and no need of chemical pre-treatment. Furthermore, the supply by low temperature heat as main energy source allows the application of waste heat from generators where available or allows the supply of relatively inexpensive solar heat, where sufficient and stable energy supply from the grid is not available. For electrical driven desalination systems such as RO units, an additional supply e.g. from photovoltaic cells (PV) or small diesel driven generator (CHP) has to be considered.

Assuming specific energy demand of decentralized RO to be 7 kWhel./m³, the additional costs per m³ are in the range of 2.8 €/m³ for PV-RO and 1.4 €/m³ for RO using generator power.

Comparing those costs with the predicted water costs of solar MEH-Desalination allows characterizing the locations where the presented system has its cost advantages compared to electrical driven RO-units and where its application makes economic sense. Among these are decentralized resorts, weekend houses, military stations, remote villages and small marinas. Saving the thermal to mechanical conversion losses allows the Multi Effect Humidification (MEH) process to compete economically with the Reverse Osmosis (RO) process for such decentralized applications. This can be enforced by use of waste heat from small diesel or gas electrical generators (combined heat and power, CHP).

Costs in €/m³ operation/total	**Heat source**	**Electricity source**	**1 m³ per day**	**5 m³ per day**	**10 m³ per day**
MEH waste heat	CHP	CHP	4.56/6.20 €	2.86/3.94 €	2.40/3.34 €
MEH solar thermal	Solar coll.	Grid	7.22/8.87 €	5.17/6.25 €	4.77/5.71 €
MEH autonomous	Solar coll.	Photovoltaic	8.8 / 10.2 €	5.94/6.78 €	5.13/5.73 €
RO grid connected	-	Grid	-	0.90 to 2.80 € /1.40 to 4.20 €	
RO – Genset	-	Generator	-	1.00 to 2.70 € / 2.80 to 5.60 €	
RO – PV	-	Photovoltaic	-	0.70 to 2.6 € / 4.20 to 7.- €	

Table 1: Cost comparison for small scale desalination methods

The final conclusion of Table 1 is that reverse osmosis has light cost advantages also at small scale applications over 5 m³ per day in installations where standard electrical grid connection is available and electricity prices are at or below 15 €Cent/kWh. In all other cases, especially when using solar energy as energy source, the thermal processes using solar thermal collectors have cost advantages in the end. The use of thermal desalination units as the MEH system should be considered for remote areas when looking at costs and easiness of operation.

Conclusion

Solar driven desalination using the MEH-method appears to be ready for market introduction from the designing and engineering point of view. Research and development, industrial prototyping as well as the long term evaluation phase have been finalized successfully.

To enter the very broad international market area-wide, efforts in economic convincing using total cost considerations and promotion aspects of decentralized systems are needed to bring thermal systems for small scale desalination. New financing models integrating water authorities and local decision makers will be needed where they make economic sense to enable equitable competition with commonly subsidised, central installations with broad distribution networks. This will be the main task of the coming years.

Country report Germany

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Introduction

The German market for solar thermal heat has been booming in 2006. The industry federation BSW Solar already identified a market growth of some 25 percent in 2005 compared to the previous year, with a newly installed collector area of 950,000 square metres. The figures for 2006 are even better: sales increased by more than 50 percent and with a number of 1.5 million square metres, the threshold of a million square metres newly installed collector area has been clearly passed for the first time. This is even more remarkable, when taking into consideration the slow down of market growth caused by the depletion of national subsidies from the Market Incentive Scheme for solar thermal systems by the middle of the year and in consequence the rejection of many applications.

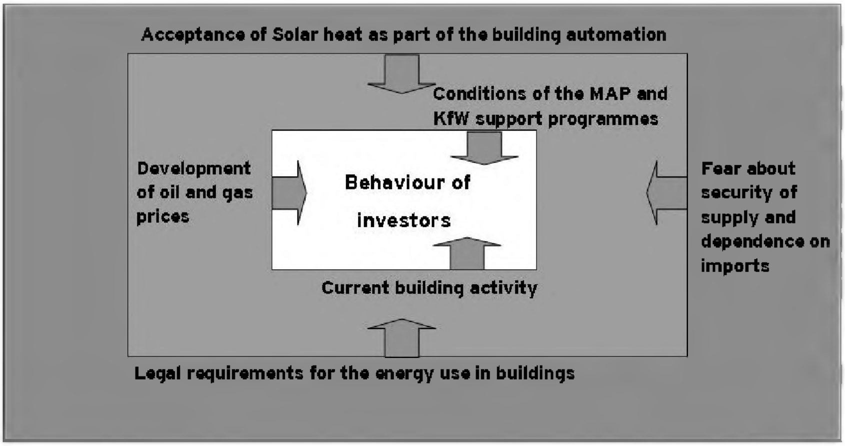
The description of the main sales trends within this country report is based on the study "Current Sales Trends for Solar Thermal Systems in Germany", published by the industry federation BSW Solar e.V. in March 2007. Since June 2007, the study is also available in English, published by eclareon GmbH Management Consultants, author of the study. Sector information in this article is based on current research of the management consultant Werner B. Koldehoff on the German and European solar thermal industry.

Overall trends for solar thermal energy in Germany

According to the industry federation BSW Solar e.V., the collector area of solar thermal systems amounted to approximately 1.5 million square metres in 2006. That is a market growth of 50 percent compared to the previous year. The total area installed therefore equals to 9 million square metres of flat plate and evacuated tube collectors on German roofs.

The sales development is being influenced substantially by a variety of market framework factors. Short term factors are the prices for material, the degree of subsidies available from public incentive schemes as well as general economic developments.

The comparison of prices for crude oil and the market demand for solar thermal solutions in 2005 and 2006 shows parallel fluctuations. The subsidies of the market incentive scheme MAP have a similar strong influence on the demand. Sudden restrictions or stops of the subsidies often resulted in an instant decrease in sales. In addition, the strong increase of building activities in Germany in 2006 had a positive impact on the development of solar thermal sales.



The building industry could overcome the downturn of the last years and the plumbers' and installation trade recorded noticeable growth in sales. Especially the renewable energy technologies profited from this development, showing a significant market growth.

On a medium and long term scale, the new legal requirements for increased energy efficiency of buildings will have an effect on the solar thermal market. For 2030, a decrease of the heating demand by 17 percent compared to 2002 can be expected, despite an increase in living space (in total and per capita). This is will happen due to improved energy efficiency of buildings, resulting from the governmental policies to reduce CO2 emissions in the building sector.

Further substantially influential factors on the market are the growing acceptance of renewable energy sources as reliable technologies in domestic application and the increasing awareness for security of supply and independence from energy suppliers. The constant high acceptance of renewable energies by the German public has been repeatedly confirmed by opinion polls throughout the past years. In addition, media coverage has had a positive effect on the awareness about security of supply and independence from energy suppliers in 2006 and at the beginning of 2007: the disruption of Russian gas supplies and possible consequences dominated the headlines.

The issue of a renewable heating law with medium or long term effects on the solar market is currently being discussed again and – depending on the outcome of the debate – could possibly come into effect from 2008 onwards. However, the model on which the law will finally be based depends very much on the political discussion.

Basically, business with solar thermal systems can be divided into business with compact systems and project development business.

Type of distribution	Trade with pre-confectioned compact systems		Project business with system packages		Project business with individual planning & design
Typical applications	One- and two-family houses		e.g. MFH with 3 - 15 flats, hotels with up to 30 beds, small trade, kindergartens etc		e.g. MFH with > 15 flats, hotels with > 30 beds, larger commercial applications
Distribution	To about 2/3 two-tier distribution from system provider (industrial representation IR) to the installer	To about 1/3 three-tier distribution from system provider (IR) over specialised wholesale trade to the installer	High acquisitional effort through the involvement into the project development with a time need of several months; the delivery of the system is then organised as two-tier distribution from the system provider or his industrial representation to the installer		
Typical systems	4-10 m² for HW* 300-400 l storage 3-7 kW nominal power	6-16 m² for combi* 450-1.000 l storage 5-12 kW nominal power	10 - 30 m² for HW 500 - 2.000 l storage 6-18 kW nominal power	10 - 40 m² for combi 750 - 4.000 l storage 6-24 kW nominal power	Starting from 30 m²
Suppliers (examples)	Over 100 system suppliers in Germany		Around 15 suppliers, e.g. Aquasol, Buschbeck, Buderus, Citrin, Paradigma, Schüco, Solvis, Sonnenkraft, Sunset, Vaillant, Viessmann, Wagner etc.		

Based on the data from the Solar Atlas (www.solaratlas.de), this report distinguishes the business fields according to the size of the collector area: systems with a size below 20 square metres of collector area are defined as compact systems, whereas systems with collector areas larger than 20 square metres are counted as project development business.

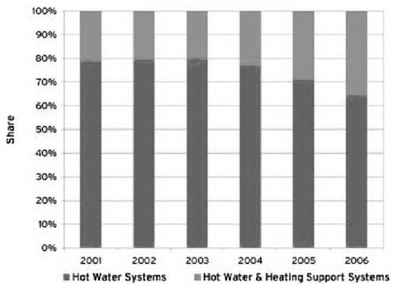
Current sales trends for small compact systems

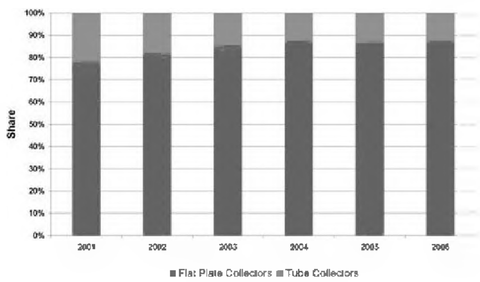
Compact systems make up more than 95% of the German solar thermal market sales and about 80% of installed collector area. In 2006 alone, the number of newly installed compact systems amounted to 110,000–120,000 with a total of 1,1 to 1,2 million square metres of collector area. Sales managers estimate a further increase of sales between 20 and 50 percent for 2007.

These high growth expectations are supported by the results from surveys on the behaviour of potential investors. More than a quarter of the house owners questioned by the SOKO institute in 2006 stated the wish to install a solar thermal system within the next two years. The results of newer polls, e.g. of co2online gGmbH at the beginning of 2007 show, that even 35% of one and two-family house owners are considering the installation of a solar thermal system in the course of upcoming reconstruction works. If these results are correlated with the predictions for boiler sales based on the pending reconstruction of one and two-family houses of approximately 600,000 future installations with an estimated solar thermal percentage of one third, an immediate potential of 200,000 solar thermal compact systems can be expected for 2007. Based on the data of the online tool "solaratlas.de" and the statements of interviewed solar thermal sales managers, the number of 110,000 systems (770,000 square metres of collector area) are estimated to be installed in the segment of domestic hot water and some 90,000 systems (1,507,500 square metres of collector area) in the segment of domestic hot water and heating support.

An additional potential of a further 50,000 installations could be expected, if every third planned new building would be equipped with a solar thermal system. The building industry estimates, that approximately 155,000 new private homes are to be built in 2007.

In interviews with sales managers of the solar thermal industry, the growing trend for solar thermal systems with space heating support has been repeatedly confirmed. This fact is also supported by the analysis of the data extracted from the Market Incentive Scheme MAP.





The results of polls by the co2online gGmbH show that house owners could favour combined systems in 2007, also interviews with the installers support this trend. According to the 770 interviewed installers, two-thirds of house owners would like to install a combined domestic hot water and space heating system. In total it can be estimated that the market for compact systems in 2007 will be made up of 60% domestic hot water and approximately 40% combined systems. This will, however, be a further sales increase for the combined solutions in comparison to the solely domestic hot water systems compared to 2006. According to the interviewed sales managers, technological and economic feasibility are the main reasons why sales for combined solar thermal systems are not showing an even higher growth.

The current motivations of potential investors have been determined by asking installers about the main reasons for the purchase of solar thermal systems. As stated by a survey in 2006, the major motivation for the investment can be found in the growing prices for conventional energy sources and the dependency on oil and gas.

The analysis of installers active in the solar thermal field by the consultancy Querschiesser showed that the business with solar thermal installations is by far the most prevalent activity related to sustainable technologies. 78,5% of the installers questioned declared that they installed or sold a solar thermal system within the past 12 months. According to experts, however, only about 15% of 50,000 plumbers in Germany could be called "solar professionals" proactively expanding their solar business.

Evacuated tube collectors are sustaining their position in the business with compact systems and sales have grown correspondingly – but they lost shares compared to glazed flat collector systems. The installers questioned stated that in 2007 an average of 2% of sales shifted from evacuated tubes to glazed flat collectors. The majority of sales managers supported this opinion and estimated that the share of evacuated tube collectors will not increase in the future.

Concerning the development of prices, the installers expect an average light increase in prices of some 2.5 percent for compact systems in 2007. According to their statements, this increase cannot be passed on to the costumers at all times. Therefore, the margin for installers could be proportionally decreasing with the price increase of the manufacturers in 2007. A problem of acceptance of solar thermal products by installers would inevitably be the consequence.

Current sales trends for large systems

Large systems for one- to two-family houses and especially for the application in multifamily houses, hotels, industrial and public buildings are mainly element of the project development business. The volume of this business still amounts only to a small share of total solar sales.

This marginal segment is dominated by some fifteen manufactures and the intensity of distribution activities is less developed compared to the manufactures selling compact systems.

The project business can be subdivided into medium-sized systems with a collector area between 20 and 30 square metres and large solar thermal systems with a collector area of 30 square metres or more. In Germany, medium-sized and large solar thermal systems are mostly planned and installed in multi-family houses. Based on the analysis of the present data, the stock of multi-family houses with installed solar thermal systems could be estimated at 10,000. This means that in a group of 1,000 multi-family houses only 3 are equipped with a solar thermal system.

Large solar thermal systems with a collector area of more than 100 square metres were mostly financed by the schemes Solarthermie2000 and Solarthermie2000plus or the respective incentives schemes of the Federal States. The cumulated installed collector area of large systems within the whole of Germany can be estimated to lie between 18,000 and 22,000 square metres – some 150 systems in total.

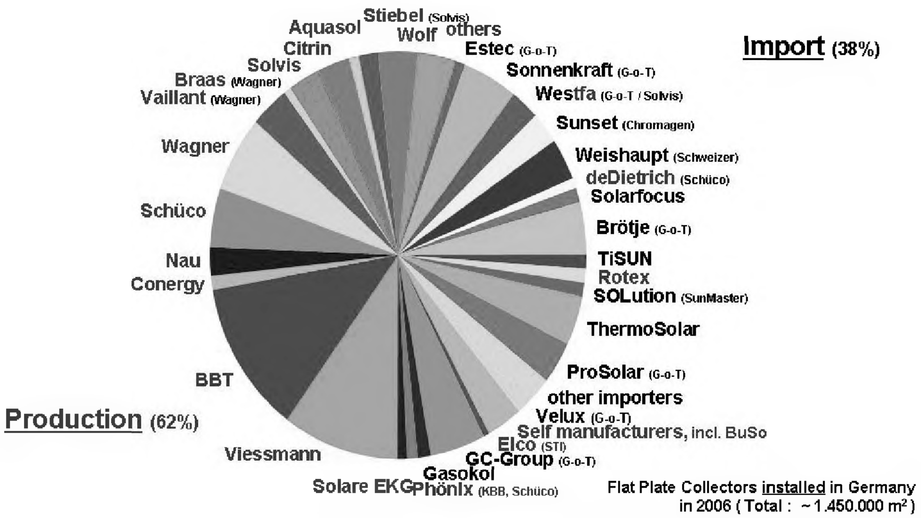
In order to determine the exploitable short term market potential of medium-sized and large solar thermal systems in the German housing sector, one would need to differentiate the owners into those living in their private houses, those renting houses and the professional housing business.

Depending on the type of owner and the legal framework for the installation of a solar thermal system, the motivation for investment varies considerably. Especially the legal barriers for dividing the costs of modernisation of the heating system between landlords and tenants make investments into solar thermal technologies difficult. For the professional housing business, the local market situation (either favourable for the tenants or favourable for the landlords) considerably determines potential marketing strategies and interest in investment. In some circumstances, an installed solar thermal system is used as a sales argument and distinguishing factor from competing housing offers.

In addition, the lack of knowledge of many architects, engineers and installers on the application possibilities of a solar modernisation is a handicap for higher market diffusion.

Market shares flat plate collectors 2006 (Source: Werner B. Koldehoff)

The division of the market of the about 1,450,000 square metres flat plate collectors sold in 2006, has been positively developing in favour of the domestic solar industry. 62% of the collectors have been produced in Germany, whereas 38% were imported from other countries (2005: 57% to 43%). From the 160,000 square metres of evacuated tube collectors installed, almost 60% were produced in Germany.



Source: Werner B. Koldehoff

With a total volume of around 1,400,000 square metres in 2006, Germany also became the European leader in production. The export, with around 450,000 square metres in total (1/3 of the production), has increased significantly. This development is mainly due to the "big players", profiting from the effects of economy of scale, some of them even reaching the position of market leaders in France or Spain.

Conclusion

The solar thermal market in one- and two-family houses is booming while, particularly in Germany, the large potential in the area of rented housing, public buildings, trade and industry remains almost unexploited. The solar industry is to a large extent professionalized and can cope with the increasing market demands to be expected with the likely adoption of a renewable heating law.

But according to BSW Solar the first quarter of 2007, however, turned out disappointingly for the German solar thermal industry. After market growth of more than 50 percent in 2006, the BDH-BSW-Solar statistics for the first months of 2007 only show a slight growth of less than 5 percent. This sales increase is only due to positive developments in January, while February and March have been weaker than in the precedent years. Several reasons can be found for this: the increase of the VAT led to anticipated investments in the past year and the energy prices have reduced the pressure to act. In addition, the reorganisation of the proceedings for granting subsidies from the MAP-Programme might have caused uncertainties. The expectation that the mild winter could lead to a growing demand has not come true, because people tend to start construction measures on the roof in the winter season only in case of an increase in energy prices such as in the past year.

The cautious start into the year 2007 also coincides with a clearly decreasing demand of heating boilers and other energy efficiency measures. Since the general framework is still favourable for the extension of renewable energies, the industry federation BSW Solar is counting with a growth of 20% in this year.

References

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Spain: Market Development and Perspectives

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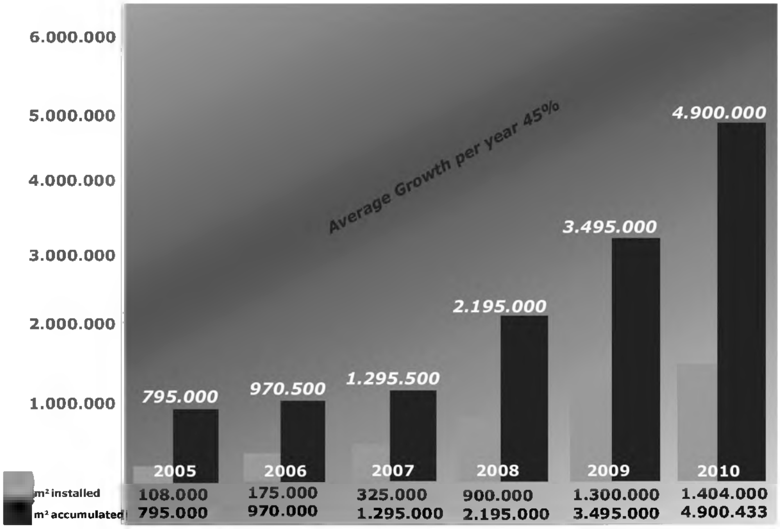
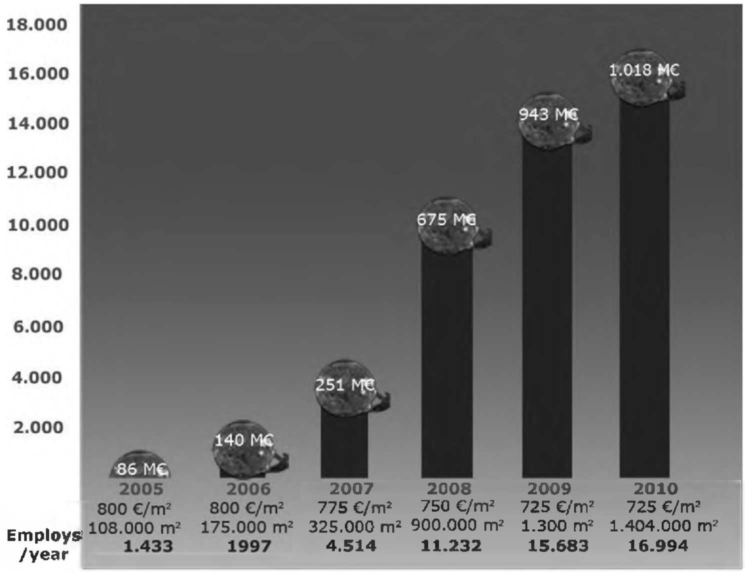
Introduction

- Solar Thermal Market in Spain
- Development until 2005
- Forecast of development: PER's Objective 2010
- Employment projection according to PER
- Solar Thermal in the CTE
- Objective Impact of PER 2005-2010
- Challenges to overcome
- Costs: The Impact in the Building
- Benefits: the Impact in the User
- Certification of Solar Thermal Panels
- Introduction to ASIT

Solar Thermal Market in Spain

- Situation at the end of 2006: 680 MWth = 970,000 M2 (ASIT's forecast at the end of 2006)
- Target for ST, Plan of Renewable Energies (PER 2005–2010):
  3,430 MWth = 4,900,000 M2 installed in 2010
- € 348 m subsidies for Solar Thermal in PER 2005–2010
- Annual growth, 45% (2005–2010)
- New installed 2006–2010 = 3,930,000 M2 = € 3,113 m invested 2005–2010
- 51,807 jobs/year 2005–2010
- New rules for homologation of solar collectors and systems: UNE-EN 12975/6.
- Test laboratories will be considered as accredited if they comply with the requirements of the UNE-EN-ISO/IEC norm 17025.


6.000.000
5.000.000
4.000.000
3.000.000
2.000.000
1.000.000
Average Growth per year 45%
795.000
970.500
1.295.500
2.195.000
3.495.000
4.900.000
2005
2006
2007
2008
2009
2010
m² installed
m² accumulated
108.000 175.000 325.000 900.000 1.300.000 1.404.000
795.000 970.000 1.295.000 2.195.000 3.495.000 4.900.433


18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
86 M€
140 M€
251 M€
675 M€
943 M€
1.018 M€
2005
2006
2007
2008
2009
2010
800 €/m² 800 €/m² 775 €/m² 750 €/m² 725 €/m² 725 €/m²
108.000 m² 175.000 m² 325.000 m² 900.000 m² 1.300 m² 1.404.000 m²
Employs /year
1.433 1997 4.514 11.232 15.683 16.994

Solar Thermal in the CTE

Royal Decree 314/2006, 17th of March: since 29th September 2006, new construction projects and/or reforms of existing buildings for any use with hot water or swimming pool heating, must have provisions for solar thermal energy (Min. 30%-north, Max. 70%-south).

Objective Impact in PER 2010:

- New Buildings (affected by the CTE), execution Period 2008–2010: 400,000 housing (average/year) Individual housing: 20% – Housing blocks: 80%.
- Renovations: 25,000 housing (average per year)
- Expected Impact: 2,700,000 M2 <=> 1,890 MWth <=> 69% of objective
- In constructed buildings (non affected by the CTE): Knock-on effect (social acceptance) <=> New applications like Heating & Cooling (mainly individual housing & service sector) and Industrial water heating
- Expected Impact: 1,230,000 M2 <=> 861 MWth <=> 31% of objective (€ 348 m subsidies PER)

Challenges to overcome:

- To train new technicians (designers, installers-maintenance staff and certifiers) <=> To cover the spectacular growth expected in the demand of associated services
- To obtain a full Architectural Integration to achieve a full Social Integration of this technology
- To reach the technological symbiosis between equipments of the principal source of energy (solar) and of the auxiliary source, achieving the aims of saving in the energetic invoice of the Country and in that of the owner of the housing or building.
- To facilitate the reduction of the costs, without resignation of the Quality, of the solar thermal installations in the building <=> achieve competition with conventional sources of energy
- Challenges, all of them, which overcoming only is possible to construct on the technical – economic consensus of: Promoters, Architects, Manufacturers, Installers & Maintenance

Costs & Benefits: The Impact in the Building and in the User

- Average costs ST per housing: 2,14 M2/housing x 730 €/M2 = 1,562 € per housing
- The saving per housing (average): 2,225 kWh per year and 2,23 CO_2 tons per year

Housing Prices (Source MVIV)				Solar Thermal Cost	
Autonomous Communities	Year 2006 I Quarter			Average / Housing	Cost Impact
	€/M2	M2/Hous.(*)	€/Hous.	€/Hous.	%/Hous.
Andalucía	1.587	112	177.789	1.562	0,88%
Aragón	1.734		194.186		0,80%
Asturias (Principado de)	1.564		175.134		0,89%
Balears Illes	2.121		237.530		0,66%
Canarias	1.658		185.674		0,84%
Cantabria	1.833		205.262		0,76%
Castilla y León	1.374		153.866		1,02%
Castilla-La Mancha	1.321		147.974		1,06%
Cataluña	2.176		243.712		0,64%
Comunidad Valenciana	1.547		173.309		0,90%
Extremadura	910		101.909		1,53%
Galicia	1.316		147.370		1,06%
Madrid (Comunidad de)	2.874		321.877		0,49%
Murcia (Región de)	1.402		157.024		0,99%
Navarra (Comunidad foral de)	1.633		182.840		0,85%
País Vasco	2.716		304.192		0,51%
Rioja (La)	1.559		174.597		0,89%
Ceuta y Melilla	1.376		154.123		1,01%
Ceuta	1.511		169.210		0,92%
Melilla	1.273		142.621		1,10%
Spain	**1.888**	**112**	**211.411**	**1.562**	**0,74%**

(*) Average: 160 M2/ One-family hous. * 20% + 100 M2/Hous. In height * 80% (Source COAAT year 2005)

Benefit of Solar Thermal (by system and by housing type and by CC.AA.)				
Autonomous Communities	(*) Energie Saving	(**) Economic Saving		(***) CO2 Emissions Saving
		Auxilliar Energy	Auxilliar Energy Source: Electr.	
	kWh/year	€/year	€/year	Tn/year
Andalucía	2.214	106,27	192,62	2,21
Aragón	2.251	108,05	195,84	2,25
Asturias (Principado de)	1.599	76,75	139,11	1,60
Balears Illes	2.142	102,82	186,35	2,14
Canarias	2.289	109,87	199,14	2,29
Cantabria	1.675	80,40	145,73	1,68
Castilla y León	2.108	101,18	183,40	2,11
Castilla-La Mancha	2.236	107,33	194,53	2,24
Cataluña	1.938	93,02	168,61	1,94
Comunidad Valenciana	2.174	104,35	189,14	2,17
Extremadura	2.213	106,22	192,53	2,21
Galicia	1.695	81,36	147,47	1,70
Madrid (Comunidad de)	2.177	104,50	189,40	2,18
Murcia (Región de)	2.495	119,76	217,07	2,50
Navarra (Comunidad foral de)	1.833	87,98	159,47	1,83
País Vasco	1.612	77,38	140,24	1,61
Rioja (La)	2.035	97,68	177,05	2,04
Ceuta	2.485	119,28	216,20	2,49
Melilla	2.361	113,33	205,41	2,36
Spain	**2.225**	**106,80**	**193,58**	**2,23**

(*) Energie Saved = 0,6 * P * G (kWh); P= Cappacity installed in Kw.; G = Radiation in kWh/M2 (Source: ESTIF)
(**) Valoration: Gas = 0,048 € / kWh; Electricity = 0,087€/kWh (Source: Energuía); Heater Efficiency 80%
(***) CO2 Emissions Saved = 1 Tn / kWh and year

Certification of Solar Thermal Panels

Due to the Spanish solar thermal market growth expected from 2008, a new regulatory framework has been established in order to certificate solar thermal panels:

– From January 2007 until January 2008, the certification of solar thermal panels must fulfil the UNE-EN 12975 efficiency test. Beyond January 2008, they must fulfil the whole set of UNE-EN 12975 requirements.

– From January 2007, the required tests for the homologation must to be done in accredited laboratories that:

1. Fulfil the requirements established in the norm UNE-EN-ISO/IEC 17025
2. Are accredited by:
    a) Entities regulated in the chapter II section 2 of the Regulation of the Infrastructure for the Quality and Industrial Security, approved by Royal Decree 2200/1995, of December 28, or
    b) By any other organism of accreditation signatory the Multilateral Agreement of Recognition of the "European Cooperation for Accreditation" (EA).

Therefore, this new law allows the tested collectors in the above mentioned Europe laboratories, to be homologate in Spain without repeating the tests in a national test laboratory, facilitating the market expansion.

Introduction to ASIT

Solar Thermal Industry Association, non governmental and non-profit, founded on April 21st, 2004. 102 members/Market share: 90%

Mission
Become a forum of meeting and representation of the sector, in order to debate ideas and develop activities that will end up with the improvement and increment of the Solar Thermal Energy Sector in the Spanish State.

Main objective
Help to fulfil, or exceed, the targets foreseen in the Renewable Energy Plan 2005–2010 (PER) for the Low-Temperature Solar Thermal Technology.

Principal goals and activities

1. Gather companies that operate in the Spanish State which activity is related with the solar thermal industry.
2. Collaborate in the promotion and the spread of the solar thermal energy usage.

3. Protect the environment as a result of the sector's activity.
4. Promote and coordinate the certification of products related with solar energy to guarantee the quality, security and respect for the environment.
5. Represent its associates in public organizations.
6. Coordination of actions in European organizations and other ambits.
7. Promote synergies and mutual collaborations with other associations that pursuit the same objectives.
8. Another related issues.

The Spanish market grew very significantly in 2006, with one estimated new installed capacity of 175,000 M2 (122 MW_{th}).

On April, 2007 ASIT represents more than one hundred companies which representation quota in 2006 was:

Market representation

- Manufacturers: 91.5% (160,000 M2/112 MWth) (1)
- Installers: 34.5% (60,375 M2/42 MWth) (2)
- Invoicing: 85 mill € <=> 61% of the total 140 mill. € (Solar Thermal in Spain)

Number of employees

Direct: 1,414 People

Indirect: 3,000 People

Source: ASIT members 2006

(1) M2 of distributed collectors, ASIT members 2006

(2) M2 of capacity installed, ASIT members 2006

Recent developments for solar thermal in Italy
Country Report – Italy

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Introduction

Italy is out of doubt one of the European Countries with the most favourable boundary conditions for the development of solar thermal (ST). Remarkable levels of solar irradiation and high prices for conventional energy set the basis for a huge techno-economic potential for solar heating and cooling. This situation could be even more appealing when we take into account the ever growing awareness on the user side.

After a first boom in the late seventies and the early eighties, the Italian solar heating market collapsed in 1987 after the phasing out of a subsidy programme managed by ENEL, the national electricity utility. For the following decade, annual collector sales remained below 10.5 MW_{th} (15,000 m²). For a long time solar thermal suffered under a poor image caused by a large number of malfunctioning plants installed during the first boom. Only since the mid of the 90ies, later than in other European countries, a consistent revival of the market takes place. Thus, the contribution to the European solar thermal market from Italy, one of the five big countries in Europe with nearly 60 million inhabitants, lays under 4% and the targets defined in the Italian White Book for Renewable Energies, 3 million m² of solar collectors installed in 2010, remain ambitious and most probably will not be reached.

The renewed commitment towards solar is also witnessed by the creation, by the Ministry of Environment, of the National Commission on Solar Energy (CNES), which deals with both ST and photovoltaics. The CNES comprises six workgroups on specific issues: global potential, legislation, buildings, research and technological development, industry and market deployment (chaired by Assolterm regarding solar thermal), training and communication.

Assolterm, the Italian Solar Thermal Association, is strongly lobbying for and supporting the deployment of Italian ST market. The association has now about 80 Members, mainly manufacturers and distributors, but covering all the chain of ST, therefore including also designers, installers, research institutes, etc. At the moment, Assolterm Members represents between 70% and 75% of the Italian market. In the last year, several big companies (e.g. Riello Group, Viessmann, Isofoton, Schueco, Merloni TermoSanitari, Bosch/Junkers, Conergy) entered the association, strengthening its professional activities as well as lobbying and communication power.

Market data

The Solarexpo market study

The Research Center of Solarexpo Fair recently carried out a market study for the Italian ST sector for 2006, financially supported by Accomandita, Assolterm, the European Copper Institute and Velux. The necessity of this study arises from the growing importance of this sector in the Italian energy panorama, in particular with regard to the present new developments of regulations and building codes. The pressing need to interact with political and institutional interlocutors has urgently demanded a clear photography of this sector and its dynamics, also in order to support short and medium term development and incentive policies. The reaction of the market actors has been punctual and almost surprising: the replies to the questionnaires sent out by Solarexpo to the Italian ST operators have covered about 90% of the total Italian market.

The situation in 2006 and the forecast for 2007

In 2006 the Italian market has reached the level of a newly installed capacity of 130 MW_{th} (186,000 m²), comparable to the markets of France and Spain, at present two of the most interesting countries regarding the growth of solar thermal.

For 2007, the forecast of the enterprises themselves are optimistic and indicate an annual market growth of 54%, leading to a yearly market of 200 MW_{th} (286,000 m²) and a total of solar collectors installed close to 1,000.000 m². The fulfilling of this "prophecy" essentially depends on the practical applicability of some measures, first of all the 55% tax reduction described below.

A correction has been applied to the data 2001–2005, since, in consideration of the survey result for 2006, it has been assumed that the data for this period were underestimated.

The "solar geography"

Located in 12 regions, the market actors of the solar thermal sector (manufacturers and distributors) offer an optimal coverage of the Italian territory. For the rest of the peninsula, a wide network of retailers and commercial agents allows to reach almost any potential customer.

The national solar thermal industry has covered slightly less than 30% of the internal market, which consequently depends still notably from imports. The snapshot of the Italian ST manufacturing industry shows the existence of several enterprises with a high grade of specialization on solar thermal (represented in 9 regions). It is remarkable that the Italian manufacturers, although being mostly small or medium enterprises, succeed in exporting about 20% of their production.

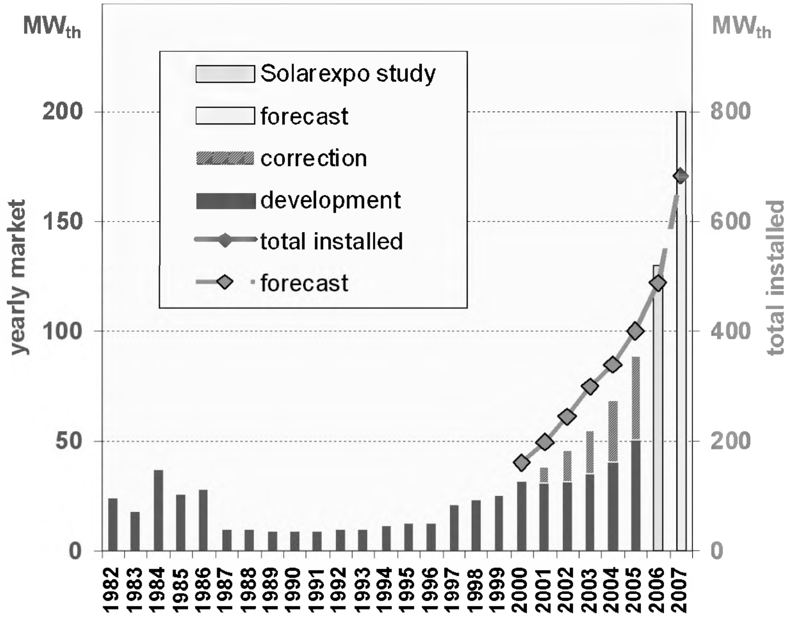

Fig. 1: Yearly market and total installed

It is further to be emphasized that, even though the north dominates in terms of commercialisation, in the centre and the south significant shares of the national production are located.

Let's square things up with solar thermal

In 2006, the Italian solar thermal industry has reached an overall sales volume of 78 millions Euro. and it offered almost 2,000 fulltime jobs.

Thanks to the predicted growth (+54%), the forecast for 2007 are a sales volume of about 120 millions € and 3,000 jobs in this sector. As reference, it can be estimated that each 70 kW_{th} (100 m^2) of yearly market a new fulltime job is created.

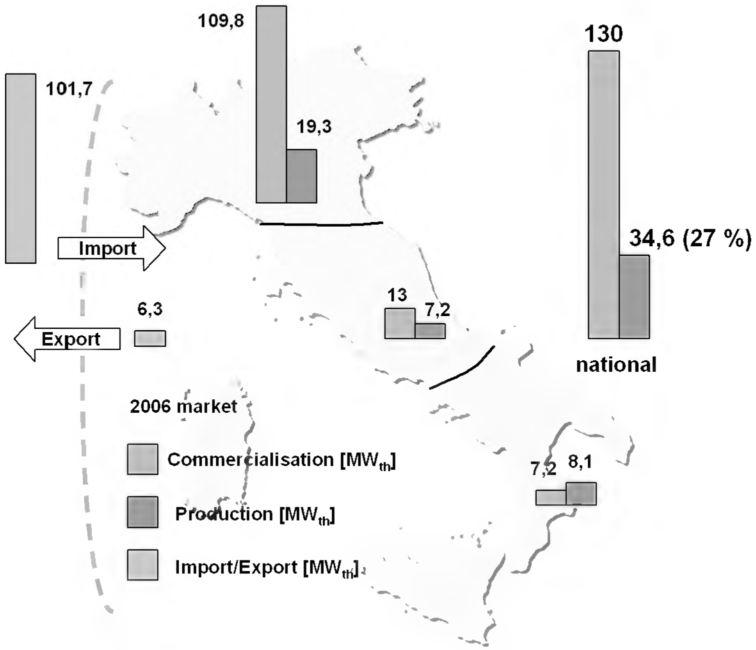

Fig. 2: Geographical distribution of solar thermal companies in Italy

The new legislative framework

The present legislative framework for ST in Italy is quite favourable. While new constructions and relevant refurbishments are covered by the new building regulation, the "non obliged" sector, i.e. already built houses, is supported through a higher level of tax reduction. These two measures are fully described in the following.

Local supporting schemes and tax reduction

In the last years, ST plants have been financed mainly through Regional supporting schemes, helped by the Ministry of Environment, by means of a contribution on the investment cost. Even though these schemes had the quite positive effect of raising interest on the technology, they also showed several negative sides, namely "stop and go" effects, too strict requirements for the solar plants (i.e. compulsory monitoring even for very small plants), with the results of higher cost and therefore lower public contributions, too bureaucratic application procedures, complicate and hardly verifiable calculation. In parallel, ST could benefit of a 36% tax reduction for building refurbishment.

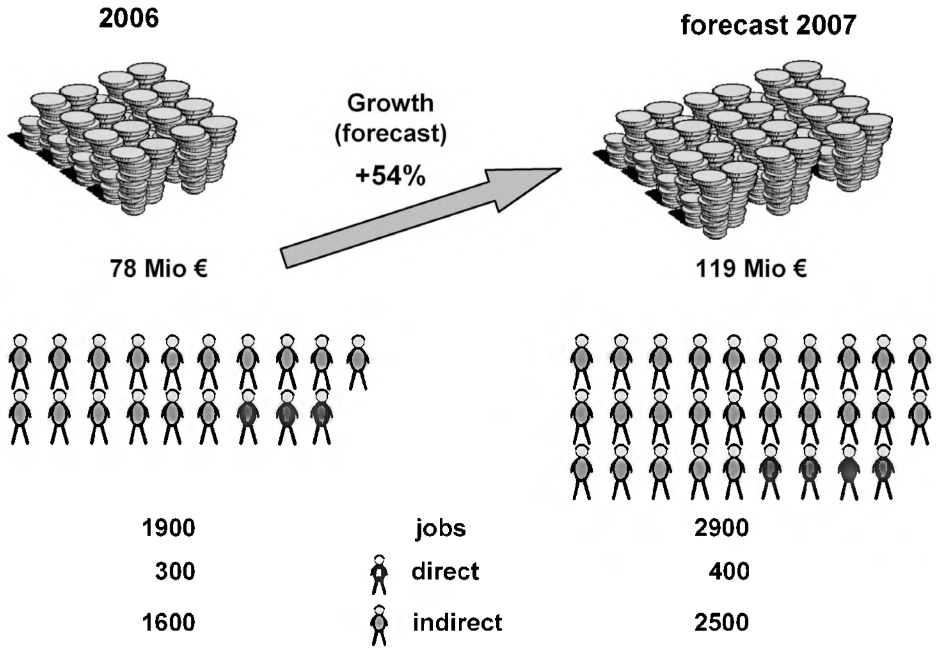

Fig. 3: Economical impact of the Italian solar thermal sector

The situation has completely changed in 2007, with the approval of the new National Financial Law, where a stronger tax reduction is foreseen for several energy efficiency measures in existing buildings, including ST. The amount of this tax reduction, which is valid until the end of 2007, is 55 % of the total cost faced by the user (with a 60,000 € cap), that could be recovered in the 3 following years. It should be highlighted that it is a tax reduction and not a tax credit: in the example reported in the table below, if the total tax amount the user has to pay for the current year is lower than 733.33 €, the difference cannot be received back as a credit, nor transferred to the next year. Therefore, if the tax amount is e.g. 500 €, it means that the difference (233.33 €) cannot be recovered by the customer.

	€
ST plant turn-key cost	4,000.00
Tax reduction (55 % of the total cost)	2,200.00
Yearly rate of recovery (1/3 of the tax reduction)	733.33

Table 1: Example of calculation of tax reduction

The reduction could be cumulated with the incentives coming from the "White Certificates" and also with Regional contributions, but not with other national contributions. The new and positive sides of this law, compared to the previous one, are several:

- the amount is 55% instead of 36%;
- recovering 55% in 3 years instead of 5 or 10, as in the previous law;
- extension of the measure to companies and not only to single users (therefore many applications of ST plants are included in the scope of the law).

Even though this measure could look as a real effective one, some doubtful aspects still have to be clarified. First of all, the documentation needed to obtain this tax reduction also requires the energy certificate of the building, whose cost is included in the "turn-key" cost of the system. Even though it could be obtained through a simplified calculation, the energy certification has no relation with the savings on domestic hot water obtained through the use of small ST residential plants, and it rises the total cost of the system. The calculation below shows that if the cost of the energy certificate is about 700 €, the actual tax reduction, taking into account the surplus cost due to the building certification, is lower than 50%. A certification cost of no more than 200 € is needed in order not to have a too high surplus cost.

	Low cost scenario	High cost scenario
ST plant cost (VAT excluded)	4,000.00	4,000.00
ST plant cost (10 % VAT included)	4,400.00	4,400.00
Cost for building energy certification	200.00	700.00
ST plant total cost	4,600.00	5,100.00
Tax reduction (55 % of the total cost)	2,530.00	2,805.00
Net cost for the user	2,070.00	2,295.00
Net surplus cost due to building energy certification	90.00	315.00
Actual tax reduction (equivalent)	53 %	48 %

Table 2: The influence of building energy certification cost on actual tax reduction

Regarding quality, solar collectors or systems must have the EN 12975 or EN 12976 certification and a minimum warranty period of 5 years. This requirement has widely increased the request for certification by collector manufacturers.

This tax reduction could be really a good measure to effectively promote ST, since it is valid at national level and all the year long. Though, in order to have a real effect on the market, the continuity of this tax reduction in the next years should be assured and this could be done only by political pressure, since the Financial Law is renewed annually. The first results has not been published yet and the whole process is monitored by ENEA. More information (in Italian) are available at www.acs.enea.it

SOLAR THERMAL IN BUILDINGS

After some local experiences (e.g. small municipalities in the Province of Milan), which were more or less successful, the solar obligation in buildings is spreading at national level, thanks to the revision of a former law, following the EU Directive on Energy Efficiency in Buildings. Law no. 311, come into effect in February 2007, foresees that at least 50% of the DHW demand must be covered by renewable energy sources, in both new buildings and refurbishments involving the thermohydraulic plant. Since it has a quite wide scope, dealing with energy efficiency in general, no specific requirements or more details are included. Therefore, an application law is now needed which must state clearly:

- which are the renewable energy sources which could be accepted for covering this minimum level of 50% (e.g. solar thermal, biomass, geothermal), avoiding, for instance, that hot water could be produced by electricity!
- the calculation method for both the hot water demand and the yield of the renewable energy supply systems;
- minimal technical and quality requirements for the ST systems (e.g. product certification, compulsory monitoring for large plants); these requirements should be clear and easily verifiable.

CONCLUSIONS

The current status shows undoubtedly a remarkable interest and demand for solar thermal on the part of the final customer. On the industrial side, the sector demonstrates to be in optimal condition, able to meet this growing demand and showing an interesting significance and relevance in terms of economics and job creation.
However, it should be clear that these are only the first steps of a long way to go.

For safeguarding, that this new growth will be durable and characterised by quality of products and installations, it will be indeed necessary that institutional decision makers put into action clear, attentive and well structured supporting policies:

- solar installers should be adequately trained in order to lower installation costs and to increase quality. Therefore Assolterm recently launched a training programme for installers, which releases a voluntary quality mark "Solar Pass Installa", quite similar to the French "Qualisol" scheme. This mark, which also foresees a "satisfaction feedback" from the user, includes at the moment about 100 installation enterprises spread all over Italy;
- a simplification of the bureaucratic permitting procedure concerning regulation on landscape protection is needed, i.e. exclusion of the Environmental Impact Assessment for ST plants, standardisation of the permitting path;

– the industrial development also has to be considered as a crucial aspect. Many of the Italian manufacturers have overcome undamaged and with a lot of efforts the "dark years" of solar thermal in Italy, with the result of having today available on the territory highly specialised enterprises. Politics must recognize in this situation the compelling occasion to flank any measures for the diffusion of this technology to the end-user, with the development of the national industry.

The goal is ambitious: regarding solar thermal contribution to mandatory EU targets at 2020, several scenarios are possible. The so called "AAU – Austria As Usual" scenario foresees the Austrian per capita level at 2020 also for Italy, meaning, in 2020, a market of about 3 GW_{th} and a total installed power of about 12 GW_{th}. An even more ambitious hypothesis is the "1 m² per person" scenario, which would lead, in 2020, to a market volume of 13 GW_{th} and a total installed power of 42 GW_{th}.

Market potential of large solar systems in Eastern European countries

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Introduction

The objective of this article is to present the solar thermal market in five new EU countries (Bulgaria, Poland, Romania, Slovak Republic and Slovenia) and especially large solar systems' potential using the GSR (Guaranteed Solar Results) quality approach. Five national reports have been elaborated taking advantage of a detailed analysis realised within the framework of the Solar Thermal Applications in EASTern Europe with Guaranteed Solar Results (EAST-GSR) EU ALTENER project.
(website: www.solareast-gsr.net)

Energy demand and potential role of renewable energy sources significantly differ between the analysed Eastern and Central EU countries.. This has to be linked not only to the size of countries but also to very different energy supply and demand situations. Despite these contrasted situations, these countries have yet common challenges: create a strong and well structured solar thermal market taking advantage of this energy source's huge development potential especially in regard with largest systems. This is exactly the aim of the EAST GSR project, which promotes a quality approach in these countries. In this paper, each country is presenting its national situation, focusing on five key elements: Energy supply and demand, Solar energy potential, National solar thermal markets, National targets for solar thermal systems, Financial supports and subsidies schemes. Countries are listed from North to South.

Energy supply and demand

POLAND

Primary energy (PE) demand has decreased by 2% from 3357 PJ in 2001 to 3284 PJ in 2005. In the same year the PE demand per capita represented 86 GJ. The share of hard and brown coal has decreased strongly, but it still represents 57% of PE supply, followed by oil (21%) and gas (13%). The share of RES is estimated between 2.5% and 4%. Biomass is currently the most important RES, followed by hydro energy. Since 2002 the final energy (FE) consumption increased by 2.75% per year and reached 2070 PJ in 2005. The share of coal FE supply has decreased systematically from 36% in 1995 to 20% in 2004. Lately oil fuels became dominant with a share of 31%. Electricity and natural gas consumption has slightly risen and reached 15% and 13% in 2004. Most of FE was in 2004 supplied to the households (644 PJ/a) and industry sector (610 PJ/a). Electricity production is primary based on hard and brown coal 94.5% with a very small contribution of hydro power plants. Other renewable sources like wind and biogas are insignificant. Ratio of FE to PE was 63% in 2004.

SLOVAK REPUBLIC

Primary energy demand in Slovak Republic has decreased by 1% from 791 PJ in 2001 to 784 PJ in 2004 (145.5 GJ per capita). The natural gas is by far the most important energy source. 76% of municipalities in the country (94% of the total inhabitants) use natural gas for heat production. Natural gas' share represents 83,7%, followed by coal (13%) and biomass (1.4%). FE consumption stabilized last year at 440 PJ per year. The share of RES in PE is 4.8%. Currently the most important RES is hydro energy (18.3 PJ/a), followed by biomass (11.5 PJ/a), waste (4.5 PJ/a), geothermal energy (1.2 PJ/a) and bio-fuels (1.2 PJ/a). 57% of electricity is produced by nuclear power plants. The shares of thermal and hydro power plants are respectively 19% and 15%. Ratio of FE to PE was 55% in 2004.

ROMANIA

Since 1999 the primary energy consumption in Romania has stabilized. In the year 2004 the PE demand was of 1612 PJ or 105 GJ per capita. Contrary to the other countries, Romania has significant fossil fuel reserves (oil, natural gas and coal), resulting to low energy dependency (30%). Within primary energy, natural gas has the biggest share with 37%, followed by oil (25%) and coal (24%). The share of RES is approx. 10% or 160 PJ per year (1/3 by hydro energy, 2/3 by biomass). Electricity consumption has increased by 11% between 1999 and 2004. Thermal power plants produce almost 66% of electricity, followed by hydro (23%) and nuclear power plants (8,5%). Final energy consumption was of 1076 PJ (2004). The same year, share of FE consumption in households, services and agriculture represented 32% and ratio of FE to PE was 67%.

BULGARIA

Primary energy demand has increased by 9,5% between 2000 and 2005 and reached 880 PJ in 2005 or 114 GJ per capita. The most important energy source in PE supply is coal with a 39% share, followed by liquid fossil fuels (24.5%), nuclear power (20%) and natural gas (6.6%). The share of RES in PE is 4.9% (biomass 35.2 PJ/a and hydro energy 7.9 PJ/a). FE consumption increased for almost 20% in the last five years and was of 423 PJ in 2005. Liquid fossil fuels have a 38% share in FE supply, followed by electricity (22%) and coal (12%). During the last decade, energy consumption in households was almost stable at 96 PJ per year. Electricity has the highest share with almost 36%, followed by district heat (20.5%) and biomass (26.5%). While electricity consumption decreased by 3% between 1997 and 2003, the use of biomass increased significantly (+14.2%). In 2005, ratio of FE to PE was only 48.2%. Energy dependency reached 70% the same year.

SLOVENIA

Continuing growth of total primary energy (PE) use was characteristic for Slovenia in the 2000–2005 period (+2.9% per year). In 2005 primary energy demand reached 307 PJ or 152.3 PJ per capita. Liquid fossil fuels had the biggest share (34%) in PE supply, followed by coal (21%), nuclear energy (21%) and natural gas (14%). The share of RES in PE supply was approximately 11% (33 PJ/a–12.5 PJ/a for hydro energy and 20.5 PJ/a for other RES). Electricity production by RES decreased from 28.6% in 2000 to 24.2% in 2005. FE consumption has grown of 2.2% per year in the last five years and reached 207 PJ in 2005. Electricity consumption's increase has mostly contributed to this growth with an annual rate of +3.8% followed by natural gas (+2,8%) and liquid fossil fuels (+1,7%). FE consumption increased in manufacturing, construction and transport sectors and decreased in households and other sectors (in households from 28.7% in 2000 to 23.7% in 2005). Ratio of FE to PE was 73% in 2005. Energy dependency reached 52.3% in 2005.

POTENTIAL OF SOLAR ENERGY

Eastern and Central European analysed countries have a significant solar energy potential. The yearly solar radiation ranges from 1000 to 1100 kWh/m2a in Poland, 1200 to 1500 kWh/m2a in Slovakia, 1400 to 1600 kWh/m2a in Bulgaria, 1000 to 1300 in Romania and 1050 to 1400 kWh/m2a in Slovenia.

GROWING NATIONAL SOLAR THERMAL MARKETS

POLAND

Solar active systems are mostly used for domestic hot water heating in single family houses. Many examples of larger systems with an area of solar collectors (SC) over 50 m² exist. They are present in schools, public buildings, multifamily apartment buildings, hospitals and sanatoriums. The solar collector market is growing (25,000 m² of SC were installed in 2004) and an estimated total area of 95,000 m² of SC for water heating is in operation. This represents a significant increase compared to the 3,000 m² SC installed before 1999, and clearly a positive signal to develop the solar thermal market for larger installations.

SLOVAK REPUBLIC

There were about 30,000 m² solar collectors installed in Slovakia till 1997, utilised mainly for tap water and swimming pools heating. Most of them were installed in individual dwellings, agricultural and industrial buildings. In the middle of the 90's about 600 m² of solar collectors were installed per year, meaning stagnation compared to 2,000 m² or 3,000 m² in the late 80's. The number of collectors installed increased quickly after 2000 but from 2003 it started to decrease again due to the higher VAT rate connected with the 19% flat tax implementation. Up to date, it is estimated that more than 50,000 m² of solar collectors are in operation and about 5,000 m² of solar collectors are installed yearly.

ROMANIA

In the 80s, solar domestic hot water systems, solar drying and cooling and industrial applications were developed. The size, variety and distribution of the installed solar systems all over the country were impressive. Till 1989, 1,000,000 m² solar collectors, mainly flat plate ones, were manufactured and installed in Romania, within large systems up to 9,000 m². After 1990, the low conventional fuel prices and the poor availability reduced the interest for further necessary efforts. A very small part (about 7%) of the installed solar systems is in operation today. After 1989, the solar thermal applications were abandoned. Only a small part of the former installed collectors is still in operation mainly for crop drying applications. After 2000 solar thermal market has started to develop once again.

BULGARIA

The first Bulgarian solar thermal systems were designed and produced in 1977. Over 50,000 m² of SC were installed in the 1977–1990 period, mainly for hot water supply in tourist facilities on the Black sea coast. Because of poor quality and maintenance, only half of installations from that time are still in operation. In Bulgaria in the last few years there was a significant increase of hotel constructions, mainly on the Black sea coast. Most of them are equipped with large solar thermal systems which underlines the great opportunity offered by tourism sector. Other large systems are installed in municipal buildings, elderly people's homes, hospitals and kindergartens as well. There is no statistic data on the solar thermal systems built during the last years.

SLOVENIA

In Slovenia, the period between 1980 and 1986 is often called the "golden age of the solar systems". The Slovenian solar industry was dominant in former Yugoslavia, and therefore mostly benefited from the "tourist boom", high inflation and low loans of that time. Different economic conditions, as well as bad experiences especially with durability of SC explain that large solar systems were not popular during the following

15 years. The solar market is now recovering and currently depends mostly on private investors. In 2005 approximately 5000 m² of SC were installed and it can be assumed that 8,000 to 10,000 m² will be installed in 2007, most of them for tap water heating in single family houses. All together 15 to 20 large solar systems are in operation at the moment, mainly in elderly people's homes and hotels.

National targets for solar thermal systems: a favourable context for solar thermal applications larger use

POLAND

The Renewable Energy Sector Development Strategy was adopted by the Parliament on August 23rd 2001. The document formulates a strategic objective, targeting the increase of the RES contribution in primary energy balance to 7.5% in 2010 and to 14% in 2020. According to this document additional 800 MWt (100 MWt of air SC and 700 MWt of water SC) will be installed by 2010, producing 2.3 PJ of heat or 1% of primary energy supply.

SLOVAK REPUBLIC

It has been estimated that, to achieve 0.3 PJ of heat supply with solar thermal systems, it will be necessary to install yearly an additional SC area of 25,000 m² between 2007 and 2010.

ROMANIA

The National Strategy on RES declares that 0,3 PJ of heat will be produced in 2010 by 215,000 m² of SC. The number of installed SC is currently very low (about 400 m²/year), a real market still waiting to be opened.

BULGARIA

National targets for solar thermal systems are based on the solar conditions and the development prognosis of solar thermal market in the country. It is expected that in 2015 the demand for heat will be of 111.9 PJ per year among which 10% for tap water heating. The production of half the necessary heat for tap water heating (5.6 PJ/a) would require an additional area of 3,000,000 m² selective SC.

SLOVENIA

The share of RES in primary energy should increase up to 12% by 2010. Among others this should be fulfilled by enlarging RES in heat supply from 22% in 2002 to 25% till 2010. The predicted enlargement of heat supply from RES should be assured mostly by introducing mid-size biomass settlements in district heating. Solar thermal systems are not in the foreground but 10,000 m² SC should be installed per year till 2010. It seems that this target of 10,000 m² will be reached already in 2007 and that the increase in the following years will probably cover the deficit from previous years. Therefore the target seems realistic, but not too ambitious.

Financial supports and subsidies schemes

POLAND

The National Fund for Environmental Protection and Water Management is the largest institution financing environmental protection projects in Poland. Loans granted by the National Fund are soft loans from 0.2 to 1.0 times the Polish base rate, covering up to 50% of total project costs. Loans are available for 20 years, however usually they are granted for 5 years. Every year around 800 projects receive support from the National Fund. EcoFund represents another pillar established by the Ministry of Finance. It subsidizes environmental protection projects, one of the priorities being solar thermal systems. EcoFund grant awarded for a single project may not be lower than 13,054 €. The grant varies between 30 to 60% of the project costs. EcoFund has also launched a so-called "fast path" of the awarding grants for development and production of solar collectors. The amount of the grant is 261 €/m2 of produced solar collector, in a limit of 2,610,000 € per year or up to 40% of the project costs.

SLOVAK REPUBLIC

Financial supports for RES exist since 1991. Currently "The Support of Energy Conservation and the Utilisation of Renewable Energy Resources" program is in operation. It consists of two schemes – "de minimis" support scheme for smaller projects (available support ranging from 2,600 € to 100,000 €) and "State Support Scheme" for bigger projects (available support from 50,000 € to 5,000,000 €). Beneficiaries are SMEs, associations of private and legal persons under 1,000 employees and organisations of state or public administration with business activities where legal persons' share is at least 51%. Environmental Fund grants support in the form of subsidy to private persons. Neither the lower, nor the upper limits of support amounts are set and there is no legal claim for the support. The condition is that the beneficiary provides at least 5% of the costs. Unfortunately these subsidies are very difficult to obtain as it is expected that the application ensures a very high decrease of pollutant emissions.

ROMANIA

According to the "Regulation regarding the state support for environmental protection" investments for renewable energy sources promotion are subsidized up to 40% of the eligible costs. Green communities (communities that cover all energy needs by RES) investments in RES can be supported from 50% to 100% of eligible costs.

BULGARIA

There are no state funds in Bulgaria for RES utilisation including solar thermal systems, but some other financial schemes are established, such as the Kozloduy International Decommissioning Support Fund. The financial support for utilisation of RES can be a grant or a partial financing system shared by various co-financing structures with other loan applications A programme between USAID and some national banks was established. Under this programme, USAID guarantees that up to 50% of the credits are available. It is quite usual that the owners of RES projects receive a 20% discount on the principal of the loan after the completion of the project.

SLOVENIA

The national strategy for promoting solar thermal application is mainly oriented on promoting solar heating systems for tap water heating in single family buildings. Last year the subsidy for private investors was 125 € per m² SC, but limited to 2,085 € for the whole system (in 2006, 788 applications with a total solar collector area of 5,100 m² SC were approved). In respect to the larger solar thermal systems, subsidies the legal investors and enterprises were available only between 2002 and 2004. It represented 30% of eligible cost. If the investor was a SME, the subsidy was enlarged by 10%. There is no tax reduction for solar system equipments at the moment. Soft loan credits are available through state owned Eco-sklad (interest rate 4%, paying off period 6 years, maximum loan 16,700 € or up to 80% of the investment).

Conclusions – barriers to overpass

POLAND

- persistent problem of solar thermal systems durability raises the issue of improving equipments quality and maintenance
- subsidies are mostly available for large solar systems and small investors don't have possibilities to get financial support.
- installations are still very expensive with long payback periods
- professional qualifications could be improved as well as knowledge about planning, installing and maintaining large solar thermal systems

SLOVAK REPUBLIC

- no accurate statistic about built solar thermal systems
- currently the solar market depends mostly on the private investors
- lack of subsidies scheme slows the market growth
- poor public knowledge

- the still low annual market of solar collectors for household systems could be developed

ROMANIA

- lack of a national program for the development of RES
- various state institutions still do not pay the necessary attention to RES
- regional and municipal structures dealing with energy planning and utilisation of RES could be improved
- no authorized laboratories for quality control of the produced equipment
- technical codes and standards could be reinforced

BULGARIA

- no authorized laboratories for quality control of the produced equipments, as well as lack of related codes and standards covering their technical requirements.
- no state funds are available for the development of RES utilisation and technologies
- RES and therefore solar energy are still not considered as a priority in the legislation and there are no incentives for their utilisation, including solar thermal installation
- commercial network is insufficiently developed as well as related market activities;
- qualified planning knowledge and technical service are insufficient

SLOVENIA

- payback time for both small and large solar systems (price around 450–550 €/m²) is quite long
- even if the national strategy document recognizes the high potential of solar energy to reduce emissions of greenhouse gasses the objectives are not ambitious;
- although international standards for solar thermal systems were adopted, they are not obligatory and there is no authorized laboratory for quality control
- subsidies scheme are developed only for small solar systems
- knowledge about planning, installing and maintaining large solar thermal systems is poor

Despite contrasted national energy situations, it is quite clear that all five countries are facing similar barriers and consequently quite similar needs. In order to develop a sustainable market, key elements are needed such as supportive subsidies schemes, maintenance and quality improvement, adapted qualifications and better public's awareness. Focusing on demonstrative pilot installations, the EAST-GSR project addresses theses issues. Its regional approach is of great relevance as it is the most proper one to enable knowledge and good practices exchanges.

Reference

EAST-GSR – Solar Thermal applications in Eastern Europe with Guaranteed Solar Results; Contract no. EIE/05/208/SI2.420214; Work package 2 "Analysis of the local situations in the Eastern European partner countries"

Overview on standards and certification issues for solar heating

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Introduction

In the last years solar installations have advanced to standard house equipment, attracting also the attention of the European legislators. Solar products, as all products, must meet certain essential requirements (e.g. related to health, safety and environment) before they can be placed on the European market. These requirements are defined by the European Union directives, which are adopted by each member country as national legislation. Several directives offer considerable support to the development of the solar market. Furthermore Public subsidies are allocated by states/communities etc provided that the product is certified under a proper certification scheme. Both legislation and certification are based on the existing standards. When needed, standards are modified to accommodate new legislation requirements.

Standardisation

Standardisation is a voluntary process based on consensus amongst different economic actors. It is carried out by independent standards bodies, acting at national, European and international level. The European Standards Organisations are CEN, CENELEC and ETSI the international one is ISO. In order to avoid double work and different standards CEN and ISO cooperate closely.

Members of CEN are the National Standardisation Bodies, e.g. AFNOR, DIN etc. Standards at CEN are developed by the relevant technical committees, e.g. Technical Committee 312 (CEN/TC312) "Thermal Solar Systems and Components", comprising of representatives of the so called "mirror committees" of the National Standardisation Bodies. Participants in these mirror committees in each country are industry, SMEs, universities, test labs, consumers, workers, environmental NGOs, public authorities, etc. This way, standards really depict the state of the art but in the same time they consume a lot of effort and time to develop.

The European standards that are now published are

Standard reference	Title
EN 12975-1:2006	Thermal solar systems and components - Solar collectors - Part 1: General Requirements
EN 12975-2:2006	Thermal solar systems and components - Solar collectors - Part 2: Test methods
EN 12976-1:2006	Thermal solar systems and components - Factory made systems - Part 1: General requirements
EN 12976-2:2006	Thermal solar systems and components - Factory made systems - Part 2: Test methods
EN ISO 9488:1999	Solar energy - Vocabulary (ISO 9488:1999)
ENV 12977-1:2001	Thermal solar systems and components - Custom built systems - Part 1: General requirements
ENV 12977-2:2001	Thermal solar systems and components - Custom built systems - Part 2: Test methods
ENV 12977-3:2001	Thermal solar systems and components - Custom built systems - Part 3: Performance characterisation of stores for solar heating systems

EN: Standard ENV: Prestandard

Standards under development

Project reference	Title
prCEN/TS 12977-1	Thermal solar systems and components - Custom built systems - Part 1: General requirements for solar water heaters and combisystems
prCEN/TS 12977-2	Thermal solar systems and components - Custom built systems - Test methods for solar water heaters and combisystems
prEN 12977-3	Thermal solar systems and components - Custom built systems - Part 3: Performance test methods for solar water heater stores
prCEN/TS 12977-4	Thermal solar systems and components - Custom built systems - Part 4: Performance test methods for solar combistores
prCEN/TS 12977-5	Thermal solar systems and components - Custom built systems - Part 5: Performance test methods for control equipment

TS: Technical Specification (previously Prestandard)

Legislation

The basic legislation applicable for solar equipment is covered by EU directives, issued by the European Parliament and the Council, which are adopted by each member country and is therefore common throughout the EU. According to the so called "New Approach":

- Harmonisation, i.e. regulation, is limited to essential requirements.
- Only products fulfilling the essential requirements may be placed on the market and put into service.
- Harmonised standards are presumed to conform to the corresponding essential requirements.
- Application of harmonised standards or other technical specifications remains voluntary, and manufacturers are free to choose any technical solution that provides compliance with the essential requirements.
- Manufacturers may choose between different conformity assessment procedures provided for in the applicable directive.

The published solar standards given above are not yet harmonised, but they are in the process of harmonisation with some directives.

CE marking

The CE marking is obligatory and symbolises the conformity of the product with the applicable Community requirements imposed on the manufacturer. The CE marking affixed to products is a declaration by the person responsible that the product conforms to all applicable Community provisions. For solar collectors no general CE obligation exists right now, but there are several ones in the pipeline. Solar equipment will need to carry CE mark standing for conformity to a constantly increasing number of requirements as these are specified in several directives.

CE according to PED

According to the Pressure Equipment Directive 97/23/EC (PED), conformity is mandatory for large collectors with high operation pressure (the essential criterion is the product of the collector water capacity and operation pressure).

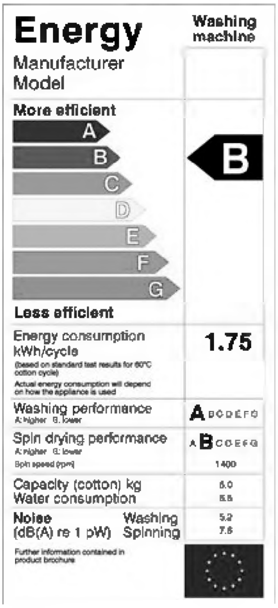
CE according to CPD

According to the Construction Product Directive, 89/106/EEC (CPD) solar collectors and systems have to conform to the essential requirements set in the directive. The existing standards will be modified, in order to become harmonised to this directive. The characteristics to be covered by the harmonised standards are:

Mechanical resistance, Fire safety, Dangerous substances, Surface temperature, Electrical safety, Max. operating pressure, Sound level, Thermal output, Energy efficiency, Thermal storage capacity, Clean ability.

These harmonized standards are estimated to be available after 2012

Energy labelling



According to the Energy Labelling Directive 92/75/EEC water heaters and water heating systems have to be labelled, by the well known from the house appliances, A, B, C.. labelling. The items on the label are Description and identification of product, Eco-label, Energy class, Annual energy consumption, Auxiliary electricity use, Size class.

The Energy Labelling can assist strongly the penetration of solar systems into the market, since it is expected that most water heaters will qualify for A energy class, demonstrating clearly and pointedly the energy savings by the solar water heater.

The existing solar standards are now being harmonised, i.e. modified to provide for conformity to the directive. These harmonized standards are estimated to be available in 2009.

Eco labelling

Eco-Design Directive (2005/32/EC) sets ecodesign requirements for energy-using products, EuP. EuP's are all products using, generating, transferring and measuring energy.

Ecodesign means the integration of environmental aspects into product design with the aim of improving the environmental performance of the EuP throughout its whole life cycle.

These harmonized standards are estimated to be available after 2010

Energy Performance in Buildings

The Energy Performance in Buildings Directive 202/91/EC (EPBD) requires different measures for energy saving and reduction of the environmental pollution. The calculation of the energy gain of the solar system and the resulting decrease of the energy consumption of the building demonstrates the advantages of solar energy and offers to the designers the means to achieve the energy consumption limits set by legislation.

In the framework of the implementation of the EPBD, standard

EN 15316-4-3 Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies – Part 4-3: Space heating generation systems, thermal solar systems was revised. It offers a very important tool for the development of the solar market.

Certification

Public subsidies, very important still in solar business, are allocated by states/ communities etc provided that the product and eventually the installation are worth the public money, this being certified under a proper certification scheme. Furthermore customers are happy when they can be sure that a certain product is "good". Since the evaluation of efficiency and quality test results, the quality assurance system, the inspection scheme etc. are not easily accomplished by a private or commercial customer, certification by a trusted third party under a solid certification scheme offers a reliable way of gaining confidence in the product. It is enough for the customer to see the quality mark on the product.

Several certification schemes exist throughout Europe. They are not of course obligatory in the legal sense but they are often necessary as explained above.

Some of the existing certification schemes in Europe are:

- In Germany Blue Angel
- In France CSTBat
- In Spain Homologation

Of special importance for the manufacturers is Solar Keymark. The Solar Keymark is a voluntary third-party certification mark. By obtaining it, the solar product qualifies for many of the different Member State regulatory and financial incentive schemes. Solar Keymark is the first internationally recognised quality mark for solar thermal products. It is based on three issues:

- Initial type testing to EN 12975 or 12976
- An implemented manufacturing Quality Management System like ISO 9000
- Annual review of QMS and bi-annual product inspection

Conclusion

Legislation in Europe is increasingly putting an increasing burden of testing and paperwork on solar market but on the same time offers a common European wide legislation framework and supports the penetration of the market by solar systems. Through the Solar Keymark certification scheme, cross border barriers are reduced. A set of sound European Standards exists, supporting both legislation and certification and a well functioning mechanism is available for the constant development of standards to keep up with new legislation.

Keymark, CE-marking and energy labelling: Acceptance and perspectives

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INTRODUCTION

The purpose of this paper is to give an overview of existing and upcoming marking and labelling of solar thermal products in Europe. In short the situation is:

- The voluntary Solar Keymark quality label is already in place since 2003, and is now working very well as the general accepted "passport" for national subsidy schemes and regulations. So far Solar Keymark is available for collectors and "factory made systems"[1]. Solar Keymark is also under consideration for solar tanks and "custom built systems"[2]
- The upcoming obligatory Energy Labelling of water heaters will also include solar water heaters. Existing standards shall be revised into harmonised standards taking into account the specific requirements for Energy Labelling given by the Commission. Work on harmonised standards will start this year and this labelling can then be in force in about 3–4 years.
- Obligatory CE-marking for solar thermal products is underway (most probably only collectors shall be CE-marked). This process is still in a very initial phase, and some years will pass before the CE-marking is in force.

SOLAR KEYMARK

The initiative to develop a common European quality label for solar thermal products was taken by the European Solar Thermal Industry Federation, ESTIF in 1999. The new CEN Keymark certification scheme was chosen as "template". Logo of the CEN Keymark is seen to the left.

The CEN Keymark for solar thermal products *Solar Keymark* is a voluntary 3rd party certification mark stating conformity with the European Standards:

– EN12975 (collectors)
– EN12976 ("factory made systems")

The main elements in the Solar Keymark are:

– Type testing of randomly taken test sample by accredited test lab
– Annual inspection of factory production control
– Bi-annual detailed inspection of product

The Keymark certification can be done only by certification bodies empowered by the CEN Certification Board.

Solar Keymark is now accepted/recognised in all[3] national European certification schemes, subsidy schemes and regulations – however still some minor add-on requirements exists in a few member states:

– Spain requires also ISO 9001 certification of the factory production control (collectors)
– Germany requires (for collectors) a declaration that the product fulfil requirements in "Blue Engel" and a special calculation showing a collector performance > 525 kWh/year.

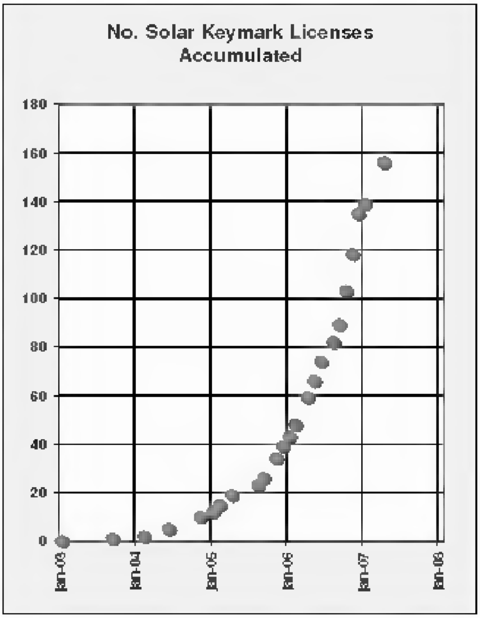
The number of Solar Keymark licenses issued has exploded in the last few years – see the figure to the right.

It is now estimated that more than half of the collectors sold in Europe show the mark.

As Solar Keymark is now specifically required for obtaining national subsidy in Germany[4] (the largest market in EU) it is expected that this "explosion" will continue the next couple of years.

So all in all Solar Keymark is indeed a success story.

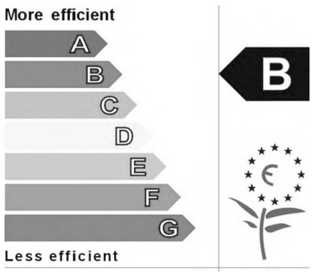
More information about the Solar Keymark is available at the: www.solarkeymark.org.



It is right now considered whether also a Solar Keymark for solar tanks should be established. The EN12977-3 "Performance testing of solar storages" is being prepared right now, and the first draft scheme rules have been drafted. If the Keymark for tanks is wanted/needed, it can be available within a year.

Germany and France have also expressed a need for a Keymark valid for custom built systems. A Keymark for custom built systems requires European standards, EN's (or a dispensation from CEN Certification Board, which was not given so far), so it is now considered to establish EN's for these kind of systems.

Energy Labelling



In the near future also water heaters must show an energy label like the one refrigerators, washing machines and other energy consuming households appliances – shown her to the left. This marking relates to the Council Directive 92/75/EEC which lays down the legal basis for a compulsory system of energy labelling and information for certain energy using household appliances.

Three implementing directives are being prepared by the Commission for the three different types:

- gas and oil water heaters and water storage devices
- electrical water heaters
- solar water heaters and water storage devices

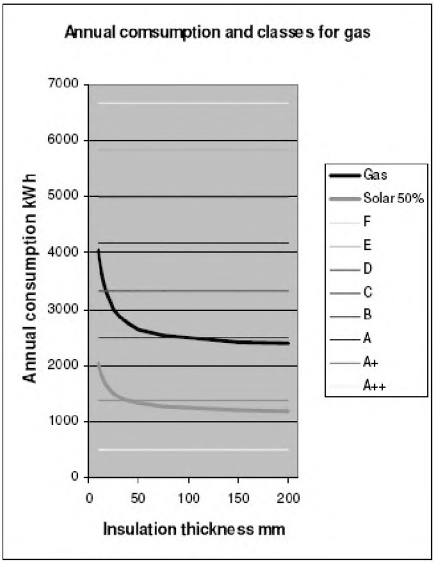
These implementing directives gives the specific requirements for labelling information to be given and refers to – so far non existing – EN standards which give the test methods to be used to provide the information.

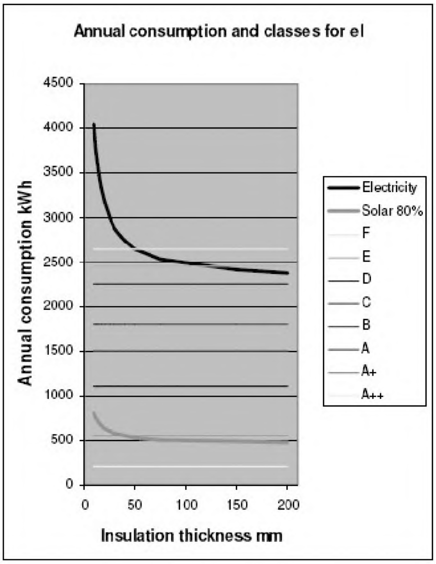
The implementing directives are so far only available in draft versions, but these draft versions give some interesting perspectives. Interesting perspectives especially for solar thermal, because the labelling is actually quite strict and in order to have an "A mark" it is necessary to have a renewable energy (read solar thermal/heat pump) input.

In the figures above the classes are illustrated – different classes for gas/oil water heaters on one side and for electrical water heaters on the other.

The thin strait lines indicate the classification levels – note that the classes are much more strict for the electrical water heaters than for the gas/oil heaters (2.5 times).

The fat curves in the figures show the annual consumption of a water heater with an average daily draw-off of 100 litres (heated from 10 °C to 60 °C) as functions of the (ideal) insulation thickness of the tank. The upper fat curve in the left "gas/oil diagram" gives the consumption of a water heater heated with gas/oil. It should be noted that an (ideal) insulation of approx. 100 mm is needed to obtain an "A-mark". In the same diagram the lower fat curve gives the annual consumption of a gas/oil assisted solar water heater with an annual solar fraction of 50%; this system will be marked "A+" if the insulation is more than 50 mm.





Same principle for the curves in the right diagram for electrical water heaters; but here the lower fat curve illustrates the consumption of electrical assisted solar water heater with a solar fraction of 80%.

To distinguish between high and low performing solar systems, the classes A+ and A++ are defined in the draft implementation directive for solar water heaters.

Interesting perspectives arise if you can convince your national authorities that only A-marked water heaters should be allowed! Or maybe give incentives to make people choose A-marked water heaters. Because then you have – indirectly – an obligation/incentive to install a solar thermal system (or maybe alternatively a heat pump).

To implement the energy labelling, related harmonised EN standards are necessary. In the near future work will to start; the existing (pre-)standards EN12976 and ENV12977 will be revised into harmonised standards fulfilling the requirements in the implementing directives for energy labelling of hot water heaters.

Expected time frame: In about 4 years the Energy Labelling of solar water heaters will be available – and obligatory – in all EU member states.

The level for stating conformity with the energy labelling will be manufacturer declaration. National authorities shall perform spot checks of the validity of the energy labels.

CE-MARKING

CE-marking of solar thermal products is also in the pipeline. Due to complaints concerning barriers to trade, the Commission has decided that existing standards shall be adjusted in order to be "upgraded" into harmonised standards related to the Council Directive 89/106/EEC for construction products. When these harmonised standards are established, solar thermal products shall be CE-marked.

Status of the process is right now that ESTIF together with the CEN Technical Committee for solar thermal systems and components TC312 has responded on the mandate proposed by the Commission. This response included among other things:

- Only collectors need CE-mark
- CE-mark shall be compatible with the existing Keymark (if you already have a Keymark it should be possible to declare the CE-mark)

The main differences between the CE-mark and the Keymark are:

- Conformity attestation
  - CE-mark:
    - Manufacturers declaration + plus type test
  - Keymark:
    - 3^{rd} party certification
- Inspection:
  - CE-mark:
    - No requirements
  - Keymark:
    - Annual inspection of production line
    - Bi-annual detailed inspection of product

Testing costs are the same for the two marks, but CE-marking will be somewhat cheaper than the Keymark, as costs for 3^{rd} party certification and inspection are saved.

Keymark is a "stronger" quality mark due to the 3rd party involvement.

The time frame for the CE-mark is rather uncertain – it could be 5–7 years.

1 "Factory made systems" are defined and treated in EN12976-1: "Factory Made solar heating systems are batch products with one trade name, sold as complete and ready to install kits, with fixed configuration. ..."

2 "Custom built systems" are defined and treated in ENV12977-1: "Custom Built solar heating systems are either uniquelt built, or assembled by choosing from an assortment of components. Systems of this type is regarded as a set of components. The components are separately tested and test results are integrated to an assessment of the whole system ..."

3 At the moment of writing the new certification scheme in UK has not been released, but we hope and expect that Solar Keymark will be accepted in this scheme too.

4 From first of January 2007 collectors in Germany not already approved for subsidy must have Solar Keymark must have Solar Keymark to enter the "approval list". From first of January 2008 all collectors must have the Solar Keymark

Standards for Collectors and Components in the pipeline

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Introduction

The European Commission has in the White Paper (1997) set the target at 12 % of energy to come from renewable energy sources by 2010, which implies that an increased use of solar thermal systems will be an important contribution. In order to get a wide spreading of solar thermal products with an open European market it is necessary to have harmonised standards for testing and mutual accepted certification procedures. Therefore, a common EU quality label for solar thermal products was established in 2003 (Nielsen, 2003). The mark is a CEN/CENELEC Mark which is called "Solar Keymark" and it is based on testing according to the EN standards for solar collectors (EN 12975) that were introduced in the same period (Wahlstrøm, 2003). (Later on Solar Keymark was also established for solar thermal systems based on the standard EN 12976.) With harmonized standards the goal to establish a fair market for testing can be reached which implies that several laboratories are accredited and experienced in performing the tests. A quality label accepted in most of Europe will give a large market access which will make it possible to avoid expensive and/or low quality products that would eliminate the market for all solar thermal products.

Even though the standard for solar collectors (En 12975) is established it is not yet universal and there are still some conflicts remaining between the standard and national regulations or requirements. To solve the conflicts and break down the barriers for an open market the standard still need to be developed and specified in certain tasks. At the same time new products are introduced at the market which also involves standard development.

Approach

One part of the ongoing Intelligent Energy Europe project Solar Keymark II is to coordinate, develop and agree on procedures for development of the EN 12975 standard. The objective is to provide inputs to ongoing and future work of standardisation group CEN TC 312 "Thermal solar systems and components", which do revisions of solar thermal standards. The work have its focus pointed either at the EN 12975 standard or on new standards to be developed covering related products or sub components. In this respect, the input can be divided in three categories:

1. direct proposals for revisions of EN 12975,
2. "resource documents" either to be referenced in EN 12975 as a support to its interpretation and practice, or to be used as drafts for future standards,
3. proposals that indicates that further work are needed.

The work is partly based on a questionnaire made in 2004 that was addressed to industries and research institutes in Europe. It was answered by 7 representatives from the solar thermal industry and by 10 research representatives. Furthermore, it was answered at a work shop in November 2004 arranged by ESTIF (European Solar Thermal Industry Federation) with approximate 25 industrial companies represented. In the questionnaire the respondents were asked to give priority to and comment on different potential working areas within this field.

The results from the questionnaires revealed a particular interest in improved exposure tests for collectors, m^2 to energy conversion, improved characterization of incidence angle dependencies, methods for accelerated testing and determination of optical properties for absorber- and reflector materials. Some of items above has been further developed within the European project NEGST (New Generation of Solar Thermal Systems) and thereafter passed on as recommendations to TC CEN 312 (Kovács et al., 2007). As the solar energy field is growing rapidly at present, the conditions and requirements for standardisation are also quickly changing. It is therefore reasonable to assume that some of the products and techniques that were of no interest yesterday will be on top of the list tomorrow. Within the Solar Keymark II project the following topics for improving EN 12975 is considered:

- annual collector energy output,
- performance and quality tests for collectors with evacuated tubes,
- collector components – requirements and test methods,
- improved exposure – accelerated ageing test of collectors.

Annual collector energy output

The most important function of a solar collector is its energy performance, the energy output during one year. Based on results from testing according to EN 12975 it is possible to calculate an annual energy output. However, the energy output might differ depending on which test laboratories that performs the calculations due to different calculation procedures. Furthermore the energy output will be dependent on where the solar collector will be located and used in practice, i.e. the outdoor climate, the tilt angle and the collector mean temperature. In order to be able compare different kinds of solar collectors from test result, independent of which test laboratory that has performed the test and where the collector finally will be located, it is important to have a standard procedure on how to calculate an comparable energy output.

A standardised procedure for calculation of the annual collector energy output based on the performance parameters resulting from efficiency tests according to EN 12975 and reference climates is now under development in the Solar Keymark II project. The procedure is programmed into an Excel spread sheet that will be available for all test laboratories and is meant to be an informative annex to EN 12975 in the future. The aim is that it should be easy to perform the calculations while still giving enough sophisticated results that can consider specific features of the most common collectors in the market, it will mainly facilitate performance comparisons for potential buyers.

The Excel spread sheet procedure is based on hour by hour calculation with the input of performance parameters resulting from an efficiency test to calculate the incident angel modifier. Other predefined inputs that should be chosen are the collector inlet temperature (25, 50 or 75 °C), location (Athens, Davos, Stockholm and Wurtsburg) and tilt angels (0, 30, 45, 60 and 90 degrees). An example of results with the Excel spread sheet is given in Fig. 1.

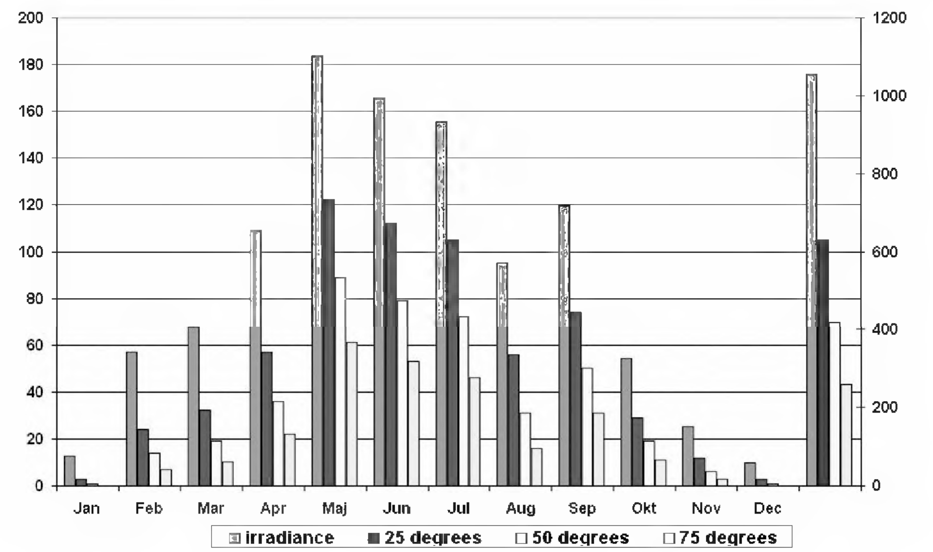

Fig. 1: Example of results for monthly and annual energy output for different inlet temperatures calculated with a developed Excel spreadsheet. The left y-axis has the unit kWh/m² and month and right kWh/m² and year.

PERFORMANCE AND QUALITY TESTS FOR COLLECTORS WITH EVACUATED TUBES

Most of the work related to development of test methods and quality criteria for solar collectors has been done mainly by considering plate collectors. Only to a minor extent has evacuated tubular collector (ETC) and its specific properties been addressed. ETC collectors today have a remarkable development of the Chinese solar thermal market. In ten years their market shares have grown from 35 to 85%. The total annual sales of collectors are around 15 million m² and growing by an annual 30%. In Europe ETCs have not been the same success so far but their shares are increasing and they have a significantly potential to contribute to a large scale introduction of solar thermal products. In order to meet this market development it is necessary that testing of performance and quality should also take the specific characteristics of ETCs into account. This is considered in the Solar Keymark II project that is developing procedures for quality and performance testing of ETCs.

The work is based on a questionnaire about ETC testing performed in 2005 among 15 test laboratories, a few manufacturers and importers (Kovács et al., 2007). The purpose of the inquiry was to give a background to an assessment of the need for revised test procedures regarding performance- and quality testing of ETCs. The questionnaire turned out to raise a number of new questions and the ongoing work is based on some of the proposals that were addressed:

- ETCs have comparatively low heat losses which results in higher stagnation- and maximum operation temperatures than compared to flat plate collectors. This means a higher probability for fault to occur during the high temperature- and exposure test that might affect the collector's efficiency. In order to reveal low quality products it is recommended to introduce a test cycle for these collectors. First the collector is measured for efficiency, then to a high temperature- and exposure test and finally for efficiency once again. In order to save costs one of the efficiency tests could be limited to zero loss efficiency, but preferably also the eventual increase in heat losses should be assessed. In order to get knowledge about the affect of introducing a test cycle measurements are ongoing with the test cycle for two types of ETCs.
- Damaging of heatpipes due to freezing can result from improper composition of the working media in the heatpipe or from bad design of the metal tube (material quality, thickness, shape of lower end) and has been reported by several sources (Kovács et al., 2007). As breakage of the metal tube in the case of bad design often doesn't occur until after several freeze cycles, a new procedure for freeze testing has been proposed and will be tested and evaluated within the Solar Keymark II project.

- The EN 12975 standard has today weaknesses of not describing in detail where the stagnation temperature should be measured and with higher stagnation temperatures it will be difficult to determine unambiguous stagnation temperature. Special attention is also required in order to avoid thermal stress on the heat transfer fluid. These problems will be more obvious for ETCs and an investigation is ongoing in the Solar Keymark II project where the stagnation temperatures are measured at different places of the ETC.
- The EN 12975 standard has today weaknesses of difficulties to determine efficiency at high temperatures with good accuracy which will be more obvious for ETCs since they have high operation temperatures. Several laboratories have reported that dry out effects can occur during testing of ETCs with heat pipes during high irradiance conditions and that the present collector model used in the standard was not able to accurately model the thermal capacitance and time constants of the collector. The method available for calculating the thermal capacity of the collector has been reported to underestimate the figures for double glass ETCs. These are also important subject for further research that is needed in near future.

Collector components – requirements and test methods

Durability testing of solar absorber coatings, anti reflective coatings, reflector materials and polymer components of solar collectors were early addressed as important subjects for improvement of standards and they have already been accepted as part of upcoming revisions of EN 12975 by the CEN TC 312 meeting in Canary Islands in April 2006.

- The absorber itself, in the collector, is directly or indirectly subjected to a number of tests in the present standard for collector testing EN 12975. Requirements for reliability are also defined. However, for the long term durability of the absorber or more specifically, the absorber coating, there are no requirements. Considering the rapid and continuously ongoing development of new materials, coatings etc. and the increasing specialization among manufacturers, it is assumed that manufacturers of absorbers could benefit from methods that can "predict" a long service life. Standardised methods and requirements would also benefit their clients, the collector manufacturers, who would then be able to strengthen quality requirements on their suppliers. A new document: "Recommended qualification test procedure for absorber surface durability" (Carlsson, 2004) describes tests applicable to organic and inorganic coatings can more or less be considered ready for inclusion in the standard.
- Polymer materials have so far only been used to a limited extent in solar thermal applications. In low temperature applications such as pool heating the introduc-

tion has been very successful and in general without problems related to the materials. On the contrary, in medium and high temperature applications where polymers were tried to replace inorganic materials, it has in general failed. As polymers definitely have many potential advantages to offer in solar thermal applications compared to traditional materials, it will be useful to researchers and manufacturers to have a set of common tools and methods to assess their properties and suitability for more demanding applications. The work to include these considerations into the standard is still within the starting phase but there are some methods that can provide an extensive input to this field.

- Another subject for improvements of standards is the increasing use of reflectors and anti reflective coatings of cover materials as a cost efficient way of improving the performance. It is a highly exposed component having a high influence on the performance, but is not assessed in the present standard. For example it is a need to be bale to assess the long term effects on the collector output. At present no standardised methods are available for this purpose.

Improved exposure – accelerated ageing test of collectors

The present European exposure test has been under a lot of debate, mainly due to its inability to maintain uniform test conditions when applied in different parts of Europe. Furthermore it is not considered to reveal the weaknesses of ETCs. Some countries have since long had stricter exposure tests than what is required by EN 12975, and one of the main objectives in the Solar Keymark II project is to eliminate such barriers. Two different methods are now evaluated within the Solar Keymark II project as new candidates for exposure test, but it is not yet clear if any of them will be sufficient enough. The test needs to have the following requirements:

- solve the basic problem of irreproducible test conditions in different locations,
- the tests should not be unnecessarily long lasting since it will take to long time to come out with new products and it will give expensive testing.

Conclusion

Only with a common accepted European mark of high quality solar thermal products will it be possible to avoid low quality products that could eliminate the market for all solar thermal products. Solar Keymark is based on testing according to good, operational and generally accepted European standards and several test laboratories are accredited to perform the tests. This is the basis for a fair market for testing and at the same time is testing in one country accepted within other parts of Europe. This will give reasonable costs for the manufactures to test their products.

As the solar energy field is growing rapidly at present it is important to continuously meet the changed conditions and requirements with improvements of the standardised test methods. With the work presented in this paper it is clearly that it is important to continuously make questionnaires to industry and research within the field to observe need for improvements and to take actions for developments.

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An Overview of Solar Water Heating in Brazil

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INTRODUCTION

In recent years, a number of studies have shown strong growth of solar water heaters sales in many countries. Absent from most studies were data for the Brazilian market, and one of the reasons is the fact that very little information about the Brazilian solar water heating market has been published to date. The present paper intends to address this problem, presenting basic information about the country and its expanding solar water heating sector.

Brazil is the 5th most populous country in the world, with a population close to 189,000.000 inhabitants. It is also the 5th biggest in terms of land area. It represents 35% of the total population and 45% of the land area of Latin America. In terms of purchasing power parity (PPP) gross domestic product (GDP), Brazil had also, in 2005, the largest economy in the region, and the 9th in the world (1). However, in terms of social development, as measured by the United Nations Human Development Index (HDI), the country occupies only an intermediate position, behind 7 other countries in the region, and in the 69th position in the world (2).

According to the Brazilian Energy Balance (3), in 2005, oil was the main energy source in Brazil, representing 43% of the total energy consumption. Electricity, which represented 16% of the total energy consumed, was mostly generated by hydroelectricity. In fact, approximately 80% of the installed capacity and 83% of the electricity generated came from hydroelectric sources. The residential sector was responsible for 24% of the electricity consumed (4). Sanitary water heating accounted to an estimated 25% of the electricity used in the residential sector (5), i.e., close to 6% of the total electricity consumption in the country is due to domestic water heating.

WATER HEATING MARKET AND ENERGY PRICES

Accordingly to a recent survey (7), 78% of households in Brazil use electric water heaters (99,7% of those are instant electric head showers), 6% use gas heaters, 14% do not use water heaters at all and only 0.37% use solar water heaters. Electric head showers can be very cheap, typically under € 15,00, but prices vary considerably depending on the materials used for fabrication, type of electric resistance and power control. More sophisticated units can cost over € 350,00. One of the biggest advantages of instant electric heaters is the fact that they not require independent hot water plumbing. However, electric head showers have a significant impact on electricity demand, and represent a key factor on the low load factor of the country's electrical system. With a typical power per unit of 5.4 kW, their concomitant use at peak hours causes a significant demand on the electricity system, particularly between 18:00 and 20:00. Instant gas heaters make up the majority of the gas market (97,6% of the gas heaters in the residential sector). Cheaper, smaller units, with nominal power around 9,5 kW, can cost as low as € 100,00. Larger units, with nominal power of 57,0 kW, typically cost around € 1000,00. Electricity is by far the most expensive energy source used for water heating. In 2005, the average price for electricity in the residential sector was 154,00 €/MWh[1], including taxes. In Minas Gerais, the state with the second highest prices for electricity, residential rates are presently around € 230,00/MWh. Natural Gas costs are lower, around € 100,00/MWh[2] and Liquified Petroleum Gas (LPG) is even cheaper, or approximately € 88,00/MWh[3] at the retail level, taxes included.

Solar Water Heating Market

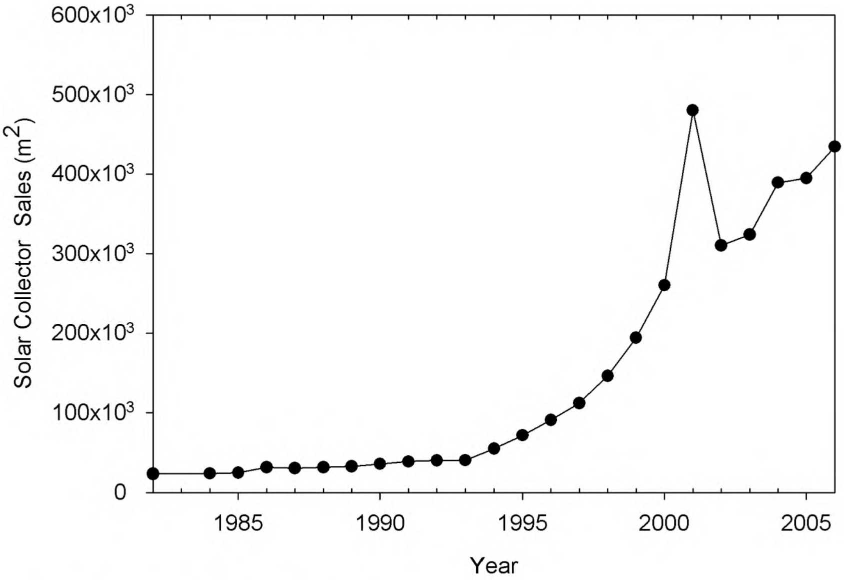

Fig.1: Yearly sales of solar collectors in Brazil. From Faria (9).

As in many other countries, the Brazilian solar water heating (SWH) market received its first impulse during the oil crisis in the early 70's. However, up to the mid-nineties the market remained very small, and SWH was only used in niche applications and few luxury homes. In the 90's, a number of factors combined to significantly strength the market. First, electricity reforms brought higher prices. Discounting inflation, from 1995 to 2000, average residential energy prices rose 40% (6), a trend that continued during the first few years of the new century. Second, the prices of solar collectors and systems were significantly reduced. This was largely possible due to materials use optimization and better sizing of systems and components. Third, the SWH industry became more organized, developing actions to improve product quality and to increase awareness of SWH. Fig. 1 presents the yearly sales of solar collectors for the last 15 years.

In 2006, sales reached 434,331 m². Imports are basically restricted to the swimming pool market. Noticeable is the large spike in sales in 2001. This was caused by an electricity supply crisis in the country, which led the government to mandate energy conservation targets. Residences, for example, had to reduce in 20% their average electricity consumption. From 1995 to 2005, sales grew an average 18% per year. During the same period, the Brazilian economy, as measured by the GDP, grew an average 2.8% per year.

There are no statistics available in terms of market segments. Therefore, the authors conducted a simple survey with top executives of 5 of the main manufacturers in the country, asking "what is your guess in terms of market share for each segment in 2006, considering collector sales (in m², not revenue)?". Again, those are not sales data, which companies are very reluctant to release, but only personal guesses, albeit well qualified ones. Four responses were received, and the results are presented in Table 1.

Sector	Residential Houses	Residential Apartment Buildings	Commercial and Institutional	Industrial	Swimming Pools
Market Share (%)	66	6	9	2	17

Table 1: Market share of different sectors in 2006, (as% of total collector area)

ABRAVA, the Brazilian manufacturers' association, estimates that until the end of 2006, 3,112.105 m² of solar collectors had been installed in the country. This number represents, using population data available for July/2006, 16,7 m²/1000 inhabitants.

Despite the significant growth in sales in the last decade, the market penetration is still very low, and far from saturation. Even if one considers that solar water heaters are financially out of reach for a significant portion of the population, a penetration of 0.37% is still far from the full market potential. There were 53,095.391 households in the country in 2005 (8). From those, 5,485.456 had family incomes higher than 10 times the monthly minimum wage (approximately € 139,00, in 2007). This can be considered the prime market for SWH. The market penetration indicates only 196,453 (0,37% of the total) households using solar water heaters. Therefore, even if all the systems were installed in houses in this higher income bracket, the market penetration for the segment would still be only 3,6%.

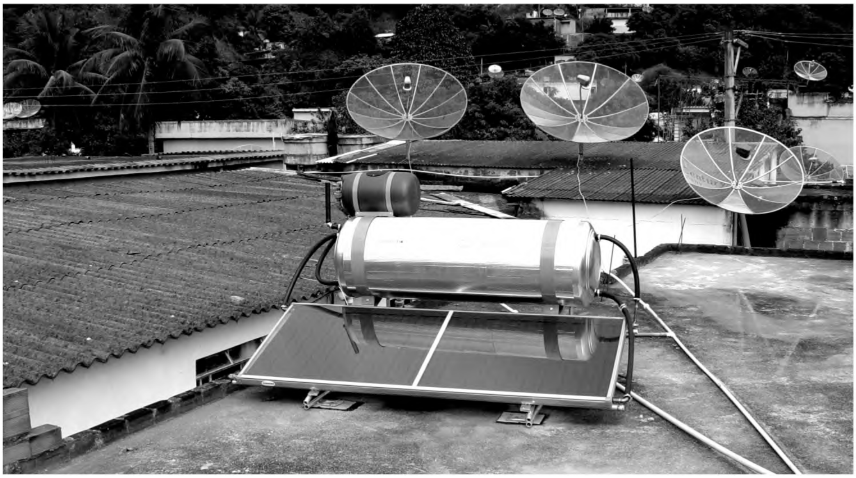

Fig. 2: Compact SWH system installed on a low-income house as part of a utility retrofit program. Photo: Soletrol.

One interesting market development is the use of SWH for social housing projects. The largest one, with almost 4,000 systems, was sponsored by Light, the electricity utility for most of the Rio de Janeiro state. Besides the main goal of energy conservation This project also targeted the reduction of delinquent accounts. Only customers with accounts in good standing were eligible for the SWH retrofit. Fig. 2 shows one installation that was part of the aforementioned project. More than 8,000 systems have been installed or planned since 2000. In those projects, there can be different mechanisms for systems financing. One option is to include the cost of the system in the total cost of the house and, therefore, the homeowner pays for the system, although the interest rates are usually subsidized. The other option is to have the SWH paid by the government or the local electricity utility, as part of mandated energy conservation programs.

Technology and Prices

Small, direct circuit termosiphon systems dominate the Brazilian market. For aesthetic reasons, most consumers prefer systems with separated collectors and tanks. Compact systems, as the one displayed on Fig. 2, are growing in popularity, but still have a small market share. Another peculiarity of the Brazilian market is the fact that almost every house has a cold water storage tank under the roof. This brings both one advantage and one disadvantage for SWH. The positive aspect is that the systems operate under very low pressure, since the cold water tank, which feeds the hot water tank, is open to the atmosphere. Typically, SHW tanks are designed for a working pressure of 0.2 to 0.5 bar. The negative aspect is that it is much harder to find room under the roof for allocating the cold and hot water tanks, respecting design guidelines for thermosiphon systems. Because of that, the tanks are usually horizontal. Fig. 3 shows two typical residential installations.

Fig. 3: Typical residential installations.

The system on the left has a roof high enough to hide the water tanks. However, the collectors are only 1 m long in the direction of the roof slope to reduce the total height required for the termosiphon operation. The system on the right has a tower built to receive both cold and hot water tanks. This solution is relatively common, since many homeowners wish to raise the cold water tank to increase the water pressure in the house.

Most solar collectors sold in Brazil are relatively cheap and of simple construction. Individual collectors cost approximately € 85,00/m^2. Under typical meteorological conditions in most parts of the country, lower efficiency, cheaper collectors are still more cost effective than sophisticated, high efficiency ones. A typical system with a 400 l tank and 4 m^2 of flat-plate collectors costs around € 1,100.00, installed. Compact systems, as the one shown in Fig. 2, cost around € 470.00 at the retail level, cheaper for larger projects. The marketplace is very competitive, and many times pricing is the most decisive sales factor. Fig. 4 presents the main characteristics of 169 collectors recently labelled through the Brazilian Labelling Program. Most of the collectors use aluminum as absorber material, mechanical bonding for absorber/tubing attachment and black paint for coating. A few years ago, there was a trend towards copper absorbers, but the trend has been reversed because of the high copper prices.

Hot water tanks traditionally have been manufactured with thin stainless steel sheets. At least one major manufacturer had copper as its main material for storage tanks, but high copper prices have forced a shift towards other materials. Polymer materials, mostly High-density Polyethylene (HDPE) are becoming increasingly popular.

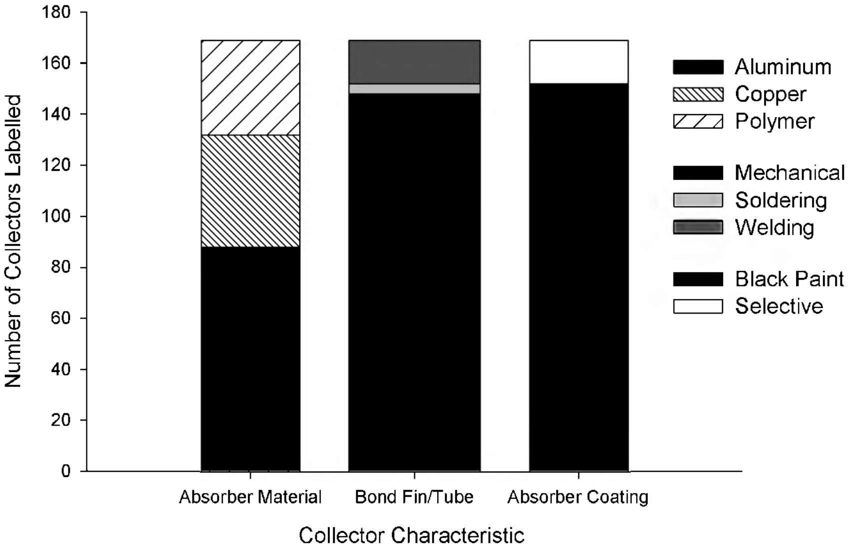

Fig. 4: Main characteristics of recently labelled collectors.

Quality Assurance Programs and Government Incentives

The main quality program in Brazil is the Brazilian Labelling Program. This is a large program managed by the Brazilian Government, through its quality and metrology agency, INMETRO. The program is applied to many different appliances and, for the case of SWH, both collectors and tanks are tested and labelled. For the collectors, the label presents basic performance data and ranks the collector according to classes (A to E). In the case of the tanks, there is no ranking, and tanks are simply approved or not. The program received a boost in 2005, with the installation of a solar simulator at the testing facilities at the Pontificate Catholic University of Minas Gerais. More details on the program can be found elsewhere (10). Another initiative is the so called Qualisol, a program directed towards companies involved with the SWH market, i.e., manufacturers, retailers and installers. The program uses different levels of qualification, depending on the size and complexity of system types to be sold and installed.

Currently there are no official government incentive programs related to SWH, although one program is currently under evaluation by the federal government. Solar water heaters are exempted of federal taxes on industrial goods and also from sales taxes, although the latter exemption expires in July 2007. Extensions have been granted many times in the past, but are not guaranteed. Municipal incentives and obligations have been the focus of the program "Cidades Solares". The program, spearheaded by ABRAVA and an NGO, Vitae Civilis, is starting to bring effective results, and at least one major city, Porto Alegre, has recently approved a by-law giving incentives to SWH.

Conclusions

The use of solar water heaters in Brazil has shown significant growth in the last decade. However, the Brazilian market is far from saturation and market penetration is still very low. The industry is well established and very competitive. There is a wide range of products available in the domestic market and pricing is a very important sales factor. Quality assurance initiatives have raised consumer confidence and product performance. Government incentives are still limited, although the federal government is currently evaluating the creation of a larger incentive program.

Acknowledgement
The authors would like to thank the financial support from the Brazilian Innovation Agency (FINEP).

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[1] at 31/12/2005 exchange rate of € 2,77 = R$ 1,00

[2] considering a High Heating Value (HHV) of 10,93 kWh/m^3 and a heater efficiency of 85%

[3] considering a High Heating Value (HHV) of 13,86 kWh/kg and a heater efficiency of 85%

Country Report on India: Solar Thermal Systems

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Introduction

India is more a continent than a country. With more about 15% of the World population staying in India it has become a country and market to recon with. At present India is more in news due it Information Technology (IT) Power but not many may know that India recognised the importance of Renewable Energy way back in 1981 (before it became fashionable like it is today) India established Department for Non Conventional Energy (DNES) and in 1992 converted the same into a full-fledged "Ministry of Non Conventional Energy" (MNES) and is perhaps the only country in the world to have Ministry for Renewable Energy!!!!

Recently it changed the name of its Ministry from "Ministry of Non Conventional Energy Sources" (MNES) to "Ministry of New and Renewable Energy" (MNRE) and it shows its ambition to make Renewable Energy the conventional energy!!!!!

Indian government has made ambitious commitment of generating 10% of its energy by 2012 from renewable source of energy.

Solar Thermal Energy the Scenario

When talking of Solar Thermal energy use the most common systems are Solar Hot Water Systems. Here there are two technologies Flat Plate Solar Collectors and Vacuum Tube Collectors

Flat Plate Collectors

In India there are more than 100 government approved and With Buro of Indian Standard (BIS) manufacturers of Solar Thermal Systems based on Flat plate collectors. Both Thermo-siphon and Forced flow systems are manufactured and installed all over India.

Solar Hot water systems have been installed for various target groups starting from domestic hot water systems for private households to multi-storey complexes to Hotels to Hospitals and for Industrial sector ranging from 100 Liters per day to 100,000 liters per day.

Where as most of the Solar hot water systems in domestic and hotel sectors are for bathing i.e. hot water at 60 degree centigrade and are of thermo-siphon type ranging between 100 LPD to 500 LPD most of the Industrial Systems are for boiler feed water preheating or Industrial applications and are of larger sizes of 1000 to 10,000 LPD (with the largest being for 110000 LPD) and are forced flow circulation system and give temperature of about 80 degree centigrade.

Vacuum Tube Solar Hot Water Systems

Recently India has seen sudden spurt in sale of Vacuum Solar Hot Water Systems mainly due to imports of cheap Chinese vacuum tube collectors and they have mainly be used in domestic hot water heating systems as the system sizes are normally small and the segment is price sensitive. Not many large systems using vacuum tubes have been installed though and that may be due to quality and life doubts among the users but these may change in near future too.

Solar Hot Air Dryers

Another area where Solar Thermal Energy has found use and applications is Solar Air Heating for drying agricultural products. Here too there are many routes that have been taken but most commonly found and used are

a) Solar Tray Dryer/Cabinet dryers:

This has been developed by a NGO in India called SEED and the dryers are of 3 sizes namely 5 kg/15 kgs and 50 kgs/day of dried product. The dryer is a cabinet with glass cover which traps the heat and it has a PV driven air blower which keeps on circulating the air in the dryer and ensures uniform spread of hot air to dry agricultural products.

b) Tunnel dryer

Where larger quantities of agricultural products are to be dried there dryers manufactured and promoted by another NGO named PEN (Planters Energy Network) are being used. In these air is pushed over flat plate collectors on the rooftops and the heated air is circulated in the dryer.

Solar dryers are fantastic tools of empowering the farmers who are normally poor due to their producing perishable goods and not being in position to sit on the products till they get better prices and thus it is normally the middle man who makes the profits.

Solar Cookers

Nearly 50% of the Worlds population cooks on open fire in hazardous conditions and thus Solar Cookers has found good support of Indian government. The Authors main topic is to share their story of Success of Solar Concentrators in India but on request of the ESTEC Organizers covered other general Solar Thermal topics. Below we share how

Solar Concentrators were introduced, promoted and commercialised in India.

A) Introduction of Parabolic Solar Concentrator SK 14 (1.4 meter diameter) in India

On our return from Germany, when seeing the need for a cooker which can cook fast at high temperatures and that could cook all traditional dishes, we realized that SK-14 Concentrator that was developed by Dr Dieter Seifert of Germany, (who was author's colleague) was ideal and thus introduced the same in India.

SK-14 Concentrator is a parabolic dish with diameter of 1.4 meter. It has a deep focus (focus inside the reflector-dish) where there is an arrangement to place the cooking vessel in the focus. The advantages are that it is save and also doesn't require frequent tracking. (it needs to be moved about every 20 minutes to face sun). The solar rays are concentrated at the focal area generating high temperature thus food kept in the cooking vessel gets cooked. The temperature attained is high enough to bake and fry. In Solar Box-Cooker it takes 1.5–2 hrs for rice/dal/vegetables etc. to cook, whereas in SK-14 the same gets cooked in about 45 minutes.

The output of SK-14 cooker is 600 W and is one of the most cost effective solar cooker when one takes into consideration and compares the price/output.

SK-14 Cookers are ideal for cooking for small and large families and (in a modular manner) for small communities, but when it comes to be used for large communities they have limitations. Not only in size but practicability as well as it still needs the cook to go out in the sun with their large cooking vessels to be placed in the focus of the dish and also needs the cook to shift/ move the dish manually to adjust to the movement of the sun.

Since in cooking for large communities the quantity of food to be cooked is large and thus the corresponding vessel also large weighing (as much as 30 kgs and above) it is inconvenient to carry such heavy cooking vessels in and out of the kitchen. Thus we realized that there was need for a solar cooker which can reflect the solar rays in the kitchen allowing cooking in the comforts of kitchen.

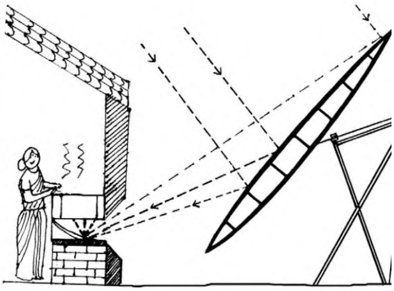
B) Introduction of Parabolic Solar Concentrator of 7.4 sqr mtr area

We were fortunate that Dr Dieter Seifert introduced us with Mr. Wolfgang Scheffler who had developed a flexible curvature dish and had installed few of them in India through/ with St Xavier's Technical Institute of Ankleshwar in Gujarat.

Realizing the potential of such cookers for India and contribution it can make in and for India on our request Mr. Wolfgang Scheffler teamed up with us to help us manufacture the same and propagate its use in India.

The flexible curvature parabolic dish developed by Wolfgang Scheffler also had automatic tracking mechanism (counter weight driven clockwork).

Due to the dish having flexible curvature it enabled and gave fixed focus and thus offered solution to both cooking in comforts in shadow of the kitchen and also being automatic. Thus there is no need for it to be tracked manually and needs to be started and focus set only once early morning and from than on the clock takes over ensuring that the dish tracks the sun automatically.

We named the dish Scheffler Concentrator after its developer Mr. Wolfgang Scheffler and are glad to note that it has become a brand name due to its success.

There are more than 150 institutions in India where the food for the community (student hostels, industrial canteens etc) is being cooked with Scheffler Concentrators. With one Scheffler dish it is possible to cook for 50–60 persons.

C) Introduction of use of use of Parabolic Solar Concentrators for Steam generation for institutional cooking ranging from 500 to 15,000 meals per day:

In 1996 we received an inquiry from Brahma Kuamri's, a spiritual organization in Mt Abu had installed 2 Scheffler Cookers supplied by St. Xaviers and who were happy when the heard that Eco Center ICNEER and Gadhia's were working on Scheffler dishes and approached us to supply them a system to cook for 1200 person. Various ideas and possibilities were evaluated, discussed and considered and many experts opinion ranging from Wolfgang Scheffler, Christoph Sutter, a Swiss Student, who had done evaluation on use of Scheffler Cookers in India, M/s HTT GmbH, a Company in Germany with whom Deepak Gadhia had worked with, were sought and finally it was decided to design a Solar Steam cooking System based on Scheffler Concentrator with M/s HTT GmbH agreeing to give technical expertise for thermal engineering, design of receivers, controls and back-up boiler.

Thus Solar Steam Cooking System is a team development between Wolfgang Scheffler, team of Brahma Kumari's under leadership of Golo Pilz a German BK disciple based in India, team of Eco Center ICNEER and Gadhia Solar under leadership of Deepak Gadhia and HTT GmbH of Germany

Brahma Kumari's were fortunate to get funding from a German government funding organization GATE (German Appropriate Technology Exchange) of GTZ under their Small Project Pilot Plant development fund and thus came up in 1997 the than World's largest solar steam cooking system at Gyan Saravor Complex of Brahma Kumaris in Mt. Abu to cook for 1200 persons.

Spurred by the success Brahma Kumari's went in for one more Solar Steam cooking System and this time to cook for 10,000 persons at their new upcoming Shantivan complex in Talati, Abu road.

The success of Solar Steam Cooking System at Brahama Kumari's has led to installation of many such more Solar Steam cooking Systems based on Scheffler Concentrators being installed in India.

Gadhia Solar has indigenized and commercialized the technology and has to its credits many installations in India and abroad. The largest being the one at Tirupati Temple that cooks 30000 meals per day with 106 Solar Concentrators of 10 sqr mtr each. Another first to their credit is the Worlds largest Solar Steam Cooking System which cooks for Indian Army in Leh, Ladakh 3000 mtrs above sea level in Himalayas.

Other Applications of Solar Concentrators

The Success of Solar Concentrators for steam generation has opened up many use of such systems for various other applications namely

- Desalination
- Waste water evaporation system
- Incineration
- Solar drying for higher temperatures
- In food processing Industries
- For Process Industry for heating with pressurised hot water, steam or thermic fluid system and Cooling

At present installation of Solar Steam Generating System to drive a 100 TR (350 kW) Vapour Absorption Chiller is underway. Normally till date single effect evaporators (VAR Systems) are being used for air-conditioning but they have poor efficiency (COP of 0.72) against the one that run on steam which has COP of 1.12 and above making Solar Cooling/Air Conditioning a viable option.

Tapping of Carbon Credits to make projects viable

It is a well known and accepted fact that Solar Systems are good for environment and save energy but the problem is that it requires high upfront one time investment due to which its spread was limited. Gadhia Solar has sold the CER's and VER's (Certified and

Verified Emission Reductions) arising out of use of its system and thus created addition stream of income for the user making the system more attractive and it also gets the user a Green Image. Thus Clean Development Mechanism is a Win-Win situation where the Developed countries are able to meet part of their commitments by investing/ funding such Solar Projects and get CERs and VERs arising due to saving in fuel and developing countries get funds to install such Clean Green projects.

Conclusion

Use of Solar Thermal energy has made substantial progress in India which now has a very big market and also a relatively large and good manufacturing base for manufacturing, designing, installing and in providing after sales service to the User and it is being promoted by Indian government not only to protect environment but to save valuable foreign exchange. Nearly 40% of the Indian governments budget is for energy and inspite of that it is energy starved market with scarcity of fuel and power and the increasing population and switching of prospering population to more energy intensive life style is bound to put pressure on the energy market endangering the energy security of the country and thus Renewable Energy and among it Solar Thermal energy is the most cost effective way of reducing the load on government and on environment.

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The American Solar Thermal Industry 2007

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A Brief History

The American Solar Thermal Industry from 1979 to 1989 was the strongest and most advanced residential and commercial solar thermal market in the world. More hot water systems were installed in the United States from 1979 to 1986 than in any other country in the world. This was created by large increases in utility prices in the late 70's and early 80's – and the 40% federal solar tax credit rebate of the first $ 10,000.00 spent, initiated by President Jimmy Carter in 1979. In 1986, the Reagan administration ended the 40% solar tax rebate and in February 1986, oil prices plunged from $ 35.00 per barrel to $ 10.00 per barrel ending the concern of the American public over rising energy prices. Over 95% of all solar contractors went out of business in1986. The number of solar thermal manufacturers dropped from 330 to 6 by 1987 and further to 5 by 1991. Solar thermal systems that were installed during the tax credit era from 1979 to 1986 were being removed from residential homes and commercial buildings, and being disposed of at a much faster rate than new systems were being installed. This was often because there were no contractors left to maintain the systems that were installed during this era.

The American Solar Thermal Industry in the years from 1986 to 2006 was almost non-existent except for a strong solar pool heating network of dealers and distributors using non-glazed copolymer collectors manufactured by Aquatherm Industries, Fafco, or Helicoil. In 2006, almost 1,500,000 square meters of copolymer solar pool collectors were installed on about 43,000 homes. Over 90% of these pool heating contractors were in Florida, Arizona, California and Hawaii. Over 80% of the contractors were installing only solar pool heating in these states except for Hawaii and a few in Florida, most had given up on installing solar hot water systems – even though most of those companies originated from 1979 to 1985 installing Solar Hot Water systems. The majority of solar hot water systems being sold were in Hawaii and were supported by large utility and state incentives – and high utility prices. Hawaiian systems usually consisted of a 302-liter tank with a 1.2 by 3 meter collector. A D.C. pump wired directly to a 10 watt PV module or a differential controller with a small A.C. pump was wired for the control and circulation system. Almost all the collectors used were flat plate collectors manufactured by SunEarth in California or Alternate Energy Technology (AET) in Florida.

These two companies manufactured over 70% of all solar collectors sold in or exported from the United States. Heliodyne recently purchased by a Danish company Solar Cap, and Radco, both flat plate collector manufacturers in California, produced about 25% of the rest of the flat plate collectors sold in the United States. There are no American companies producing evacuated tubes. A few states that had incentives for solar electric systems produced a significant market for PV systems. These were in California, New York, New Jersey and a few others. However, only a few of those contractors were installing solar hot water systems in 2005. New incentives that began in 2006 are slowly forcing residential PV contractors in this market to add solar hot water to their marketing programs in order to be competitive in the marketplace. Most of the "solar" media news in the U.S. is about solar electric systems, thermal systems are almost completely ignored by the American mass media. However, when homeowners who have caught the "buzz" about "solar electric energy" contact a solar contractor who offers both systems – the net result is that over 80% would choose to buy a thermal system once they learn the benefits and cost of both systems. Global warming or climate change awareness is also resulting in a small increase in sales from concerned citizens. Interestingly enough, the Environmental Green Movement regarding clean air and clean water in the 1990's – resulted in almost no increase in sales. Rising ocean levels – to climate crisis already noticeable in America is getting the attention of concerned citizens that want to take the responsible action.

The New Era – 2006 Onwards to 2008 or 2016?

The Federal government passed a 30% tax credit capped at $ 2,000.00 for solar hot water systems for residential homes and an unlimited 30% tax credit for commercial systems with a five year accelerated depreciation of the initial cost. This federal incentive was bolstered in many states by state and/or utility company incentives. However, most solar pool heating companies that made up 90% of the solar thermal market chose not to reintroduce marketing of solar hot water systems in 2006 because the federal incentive would end in 2007 and were extended to 2008 only in December of 2006. There is an effort through the Solar Energy Industry Association (SEIA) to work with leaders in congress to extend the renewable energy credits to 2016. Details of the current Federal Credit and efforts to extend the credit can be found at the SEIA website (www.seia.org). This website also informs the residential and commercial purchaser of solar systems how different states and federal tax credits interface with tax law. A national database of state solar incentives and laws is available at www.dsireusa.org. The contractors who did choose to expand their companies to market and install solar hot water systems saw remarkable off-the-chart growth in 2006 and early 2007. The domestic sales of the major flat plate collector manufacturers SunEarth grew over 150% and AET grew over 400% in 2006.

Most of the growth was because the utility prices in the United States rose 20 to 35% from 2005 to 2007. My Company, ECS Solar Energy Systems went from installing one hot water system per month in 2005 to 20 per month in 2007. A classic example of company growth can be seen in this Chicago Illinois example; Solar Service, Inc. (www.solarserviceinc.com) in 1985 had 16 employees and over 1,000,000.00 in sales. In 1986, it had one employee and $ 90,000.00 in sales in 2006 it had 21 employees and 2.5 million in sales.

Interestingly the homeowners who contacted local solar contractors because of the increasing utility prices knew almost nothing about the federal tax credits, state incentives or utility rebates. Over 80% of all these customers who found out about these incentives choose to install a solar hot water system. The federal government and most state governments unfortunately have no effective programs to inform or promote these incentives to the public. The utility companies that have incentives have made meager efforts to promote solar hot water systems – yet over 50% of their customers have little or no knowledge of their incentives or federal and state incentives.

Slowly the word is spreading, mainly by referrals and "word of mouth". A strange American phenomenon is that every time gas prices for automobiles surge upward sales increase proportionately in both solar hot water systems and solar electric systems as more homeowners contact existing solar contractors. Nothing gets the American consumer more agitated than price increases at the gas pump.

The new housing market is not marketing solar thermal systems to the public. Less than 1% of the residential builders in the United States offer solar thermal systems, solar electric systems or let their customers know that these incentives are available

New Contractors and Certification

Slowly at a steadily increasing rate, the number of solar thermal contractors and sales are dramatically climbing. The biggest problem has been the lack of trained contractors to meet the demand and education for contractors. One significant effort underway has been to verify contractors who have the basic skill sets and experience in installing solar hot water systems. NABCEP, (North American Board of Certified Energy Practitioners) (www.nabcep.org) which had previously created a Solar Photovoltaic Installer Certification created a task analysis for Solar Thermal Installer Certification in 2005. In late 2005, I wrote the study guide for the exam and in the spring of 2006, a panel of experienced solar thermal professionals created the exam for certification for Solar Thermal Installers. The first exam was given in the fall of 2006, and the number of individuals applying to take the exam is rapidly increasing. The certification is for experienced solar hot water and/or pool heating installers. Only two states have solar contractors' licenses, Florida and California. This NABCEP certification helps consumers find qualified installers with distinguishing credentials, and national certification within the solar thermal industry. Although it was not the intention of NABCEP – many states rebates for solar systems are now tied to having NABCEP certified installers. NABCEP certification provides consumer confidence that solar thermal systems will operate safely and to system specifications, and are being installed by a contractor who has the experience verified by NABCEP. A NABCEP code of ethics applies to solar thermal certification. Every three years practitioners who pass the exam are required to take 16 hours of continuing education in order to renew their certification.

My 240 page book "Solar Hot Water Systems, Lessons Learned 1977 to Today" is considered the definitive manual on how to install high performance, low maintenance hot water, space heating and pool heating systems using currently available technology in the United States. This is the only professional manual available in printed form for solar thermal contractors printed about the United States. Unfortunately, no documentation about the experience of solar contractors and other lessons learned from 1977 to 1986 was available to new solar contractors in the United States. In 2001, I wrote this book because I felt that the market would come back and was concerned that no new books had been published or re-published since 1983.

Where Will the Growth Come From?

From 1979 to 1983 major American corporations like Northrup, Exxon, Revere, Copper-Brass, Olin Brass, Grumman, General Electric, Carrier and Lennox entered the market. That is not going to happen in the new era.

There are not enough existing solar thermal contracting companies, or solar electric contractors who want to expand their market to solar thermal systems to grow the industry. Almost all of the growth will come slowly out of the HVAC companies, especially those doing radiant floor heating systems. Many HVAC (Heating Ventilation and Air Conditioning Contractors) companies in the northern United States have chosen to expand their product line to include solar thermal systems. Anyone planning to market their products at HVAC conventions or product shows in the United States could show their products at these venues if they expect to gain new customers.

No major college or university offers training in solar contracting. Several Junior Colleges (2-year schools) added solar electric and solar thermal courses to their curriculum. Solar Energy International (www.solarenergy.org) has the only organized training school that offers solar thermal among other classes each year. American and foreign manufacturers' have realized that you had better be ready to provide a training program for contractors who would install their system.

An even more serious problem is the lack of professional engineers who know how to design large arrays of solar thermal collectors for commercial systems. There is a huge demand for experienced commercial design engineers and installation supervisors and installation teams.

Entry into the American Marketplace

Solar thermal collectors are required to be tested and certified by the SRCC (Solar Rating and Certification Committee, www.solar-ratings.org) or FSEC (Florida Solar Energy Center, www.fsec.ucf.edu) in order to qualify for the federal tax credits and most state and utility incentives. The SRCC standards for testing solar collectors and system certifications are run by the Florida Solar Energy Center (FSEC) are based on test standards that are the same for SRCC and FSEC. The hardest part of these tests to pass is the thermal shock test. Many evacuated tubes shatter under this test procedure and fail to reach certification.

Drainback and pressurized glycol antifreeze systems are the most popular indirect systems. To be a successful contractor, you must have both systems for the marketplace. Drainback systems with and without glycol are becoming the most popular indirect systems. Drainback systems are the simplest, most reliable, have the least maintenance and the collectors last much longer than pressurized glycol. Unfortunately, drainback systems do not lend themselves to modular systems like solar stations and people who do not understand gravity. Most successful American manufacturers are selling contractor direct and *these contractors are developing their own distribution networks* with allied contractors. The market will not allow manufacturers to be successful who go through traditional plumbing or HVAC distribution chains because it adds too many price points to the contractor to be competitive in the marketplace.

A major European success has been the entry of the Steca controller into the United States marketplace in 2006. Marketed by SunEarth within the last ten months the Steca controller gained over 70% of the marketplace for differential controls. Many American contractors choose to use small PV modules wired directly to a D.C. pump for small open-loop direct systems and closed-loop indirect pressurized glycol systems. American contractors do not like pre-packaged systems like those installed in Europe – they prefer to train the installer to install individual components systems at the site or pre-plumb them before arriving at the site. American contractors prefer that the employees themselves thoroughly understand how and why the components function.

A major product that awaits development in the United States is the low pressure high ammonia concentration with water air conditioning system developed by Dr. Eric Farber in the 1950's. This system was successful using non-selective flat plate collectors. Experiments trying to use flat plate collectors with lithium bromide systems or evacuated tubes in humid climates in the U.S.A. continue to prove unsuccessful. This low-pressure ammonia air conditioning system developed by Dr. Erich Farber can be effectively operated in 140° to 160 °F-temperature range.

Solar Thermal Market in Thailand

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Introduction

Thailand has a typical history in the use of solar thermal applications, like many other countries, which despite a lot of sunshine, failed to use solar thermal applications in the past. In the last 20 years around 60 000 m² of flat plate solar collectors were installed, mainly in hotels and hospitals. Most of the installed systems are now older than 10 years and are hardly in operating any more. The recent market promotion project shows that there is a market for around 600 000 m² to be installed in the next 10 years, if a minimum of supporting policies are installed. The recent upward trend of the market is a good sign, that commercial customers do recognize the technology as a mean to save their energy costs.

Concept of the EC SolTherm Project (April 2006 to March 2007)

Against this background an EC (European Community) SPF (Small Project Facility) supported project implemented by ISE (Fraunhofer Institute) Freiburg, Germany; JGSEE, Bangkok and IIEC (International Institute of Energy Conservation), Washington/Bangkok) started in early 2006 to tackle the situation. First the market situation, their failures and lessons learnt were analyzed. Stakeholder meetings with concerned institutions and government bodies were held to analyze the existing supporting policy and the framework conditions for the technology application. In addition several stakeholder meetings with all solar companies (now more than 18) were held in Bangkok to analyze the current market situation, to present the results of the market assessment and to analyze the knowledge, the capabilities and the experience of the suppliers and manufactures. In addition through these workshops inputs were provided to the companies, e.g. how to monitor solar systems, how to dimension solar systems with the help of simulation tools and how to improve the quality of the systems installed. Cooperation with European manufacturers was strengthened to improve the quality of the manufacturing and the design of the systems. At the end of the project two dissemination workshops (Business-to-Business) were held, were more than 12 manufacturer displayed their technologies in exhibitions to more than 150 potential customers from hotels, hospitals and industry. Lectures about the market situation, how to design systems, etc. were given. At the final workshop a decision of the local manufacturer was taken to found soon a "Thai Solar Thermal Association" to request jointly a solar thermal policy that promotes this technology in Thailand, do joint marketing events, like these workshops and to introduce a voluntarily "code of good conduct" by its members. Additional information can be found on the web page of the project: http://www.soltherm-thailand.net which will act as a kind of clearing house for solar thermal information in Thailand in future. It is in English and in Thai language, as there is no information available in Thai language, which is a major obstacle for the local customers.

Barriers – Lessons from the Past

The main technical barriers can be defined along the planning, installation and operation process of solar thermal systems:

1. The knowledge for correct planning, design, selection of appropriate components and material as well as correct installation of solar systems was not available with the suppliers/manufactures of solar thermal systems.
   - 1.1 The sizing of the large solar system was done based on "rules-of-thumb" and not based on measurement of the actual hot water demand.
   - 1.2 The sizing of the components and optimization of the larger solar systems was done without using dynamic simulation software.
   - 1.3 Corrosion aspects were neglected by selecting the wrong material.
   - 1.4 Used material and components were of inferior quality.
2. Neither the customers nor most of the suppliers cared for the solar systems during operation in an adequate way. (Many systems are covered with dust.)
3. No monitoring and measurement equipment was installed to monitor status and document "saved" energy.
4. In residential applications no central hot water system exists. Typical Thai houses and buildings are not designed for hot water service. Low hot water demand in domestic sector and in low budget hotels.

=> Therefore this customers group is not suitable for solar thermal systems in Thailand.

5. Lack of integration of SWH into the building design of larger buildings/hotels.

Non-Technical Barriers

6. Relative high investment costs for solar thermal systems compared to electrical heater or LPG boilers, lead to pay-back periods, which are sometimes higher than accepted by customers.

   Static Pay-Back Period:

   around 6 years against LPG boilers (LPG is still subsidized in Thailand)
   around 5 years against Heavy Fuel Oil (HFO), but

   less than 1 year against electrical water heaters.
7. Missing standards for collectors and systems performance lead to a non-transparent market. The performance of different components and systems can not be compared easily. The consequence is that the marketing of the solar systems is done purely over the prize, regardless of their performance.
8. Testing of components and systems is not done, no test stands are functioning. Quality labels and certification schemes do not exists.
9. Lack of any financial incentives by the Government.
10. Lack of awareness activities, no ongoing demonstration or promotion activities
11. Finally a lack of a long term policy to promote solar thermal applications. So far it does not exist.

=> It is expected, that due to the Soltherm project the respected government body will start formulating an adequate policy.

As energy pries raised sharply in 2005 more and more hotels got interested in solar water heating and the few existing companies could get first major contracts. The new systems include more quality components, their planning is based on measured hot water demand, the optimization is done with dynamic simulation tools and heat measurement equipment is installed to verify savings.

Overview on Solar Water Heater (SWH) Industry in Thailand

Based on the market survey it is very likely that imported SWH products in Thailand have their origins in Australia, China, Japan, Germany, Israel and USA. The import statistics also indicate that the country of origins have been shifted from Australia and European countries (Germany and Israel) during 1990–1996 to China, Germany and Israel during 2001–2006. It should also be mentioned that the CIF import values have been increasing over the past couple years in line with rising of crude oil price in the world market. The Fig. 1 shows the current trade flow.

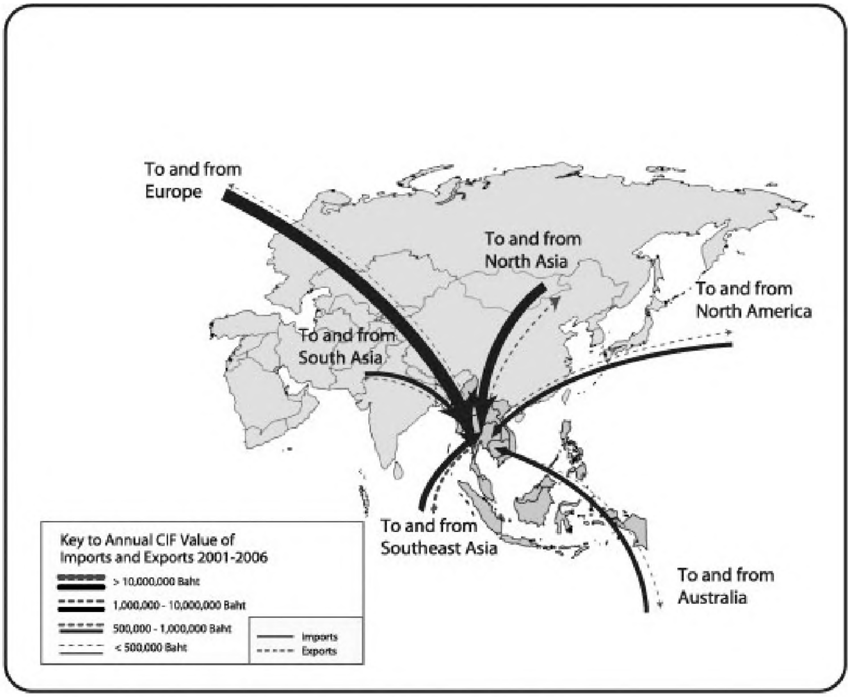

Fig. 1: Non-Electric Heater Trade Flow for Thailand during 2001–2006

Solar Water Heater Suppliers – Current Market

The existing market of solar water heater is relatively small in Thailand and only a limited number of SWH suppliers (importers, assemblers and manufacturers) is available to serve the emerging demand majority in residential and commercial sector. As the suppliers did not provide concrete sales figures a market survey was done and an anonymous questionnaire was used to assess the market size. The result was, that the project estimates the current annual market size with around 5000 m² /a. For the near future the suppliers predicted a market for collector area of around 10–20000 m² /a for 2008.

It is important to note that SWH is normally not the core business of these SWH suppliers in Thailand and classification of these SWH suppliers as importers, assemblers and manufacturers is made based on how they supply solar collectors as other system components are either locally made or purchased from other suppliers. Most of SWH suppliers in Thailand are already in the business of providing either water heating solutions or solar energy technologies for residential, commercial and industrial end-use, and SWH is an additional business line offering to their customers. There are also few Thai companies set up with core business on SWH and most of these are small importers. Given the limited SWH market size in Thailand, the existing SWH suppliers must offer one-stop-service for their customers, meaning all designs, equipment sourcing and selections, installations and maintenance. Unfortunately many suppliers do not have sufficient capacity to provide such one-stop-service requirement and this, hence, has resulted in poor performance and durability of relatively expensive SWH systems in Thailand.

Table 1 shows a full compilation of all 28 companies involved in SHW in Thailand since 1985, but only those that are still active. (An additional 7 companies were active in the past, but went out business.) As the total SWH market size in Thailand is still limited, the market demand is therefore not consistent. Most local SWH suppliers in Thailand need to utilize their other business lines to cover their operating expenses when SWH demand becomes diminished. This scenario brought some importers, which had SWH as their core businesses, into deep trouble during the 1997 economic crisis and only approximately 50% of all SWH suppliers were able to survive that downfall. After 2000, the Thai SWH market began to experience a new wave of SWH suppliers, both local manufacturers and importers from China and Germany, and most of them are still active in the market. Most SWH importers in the Thai market in the 80s and 90s imported their collectors from Australia and Germany where domestic SWH markets are mature with a number of manufacturers. During the early development stage of the Thai SHW market, imported solar collectors, mostly from Australia, were able to capture a large market share, over 80%, and SWH was considered as the premium product for medium- to high-income families due to their high investment cost. Imported SWH products from European countries (mostly from Germany and Israel), and China have been able to strengthen their market positions. In general, German SWH product importers have better technical capacity and are able to serve both residential and commercial customers. For Chinese SWH product importers, only the large ones have sufficient technical capability to serve more technical intensive commercial sector demand. Most small Chinese product importers have focused on the residential sector selling partly via home appliances stores.

Name (Co. Ltd)	**Type**	**Marketing since**	**Brand**	**Country of Origin**
Bermuda Thai	**M**	1985	Bermuda Super	Thailand
Forbest	I	1985	Everhot (China), Heatrae Sadia (UK), Rycroft (UK)	China UK
Pranee Tech	I	1985	Solahart Stiebel Eitron Solar Lee	Australia Germany Canada
Water System and Service	**M**	1990	Solar Ultra	Thailand
B.B. Business Pattaya	I	1992	Edwards	Australia
Heritage	**M**	1992	Heritage	Thailand
J-7 Engineering	**I, M**	1997	Ecotech (Thailand) Rheem (Australia)	Thailand Australia

Electricity Generation (EGAT)	M		EGAT	Thailand
Force Link	I	2000	Sunlink	China
Infratech Engineering&Services	I	2000	Edwards	Australia
Solason Solar Energy (Thailand)	I	2000	Solar Plus	China
SMT Hitech Ltd., Part.	M, A	2001	Sun	Thailand
Solar Solutions	A, I	2002	Flexi-Line, Tinox	Germany
Sunluck Solar Power	M	2002		Thailand
Chuchuay Trading Group	M, A	2003	Suntech	Thailand
ENVIMA (Thailand)	I	2003	ENVIMA Solar Technology	China (German design)
BNB Inter Group	M, A	2003	Solar Bank	Thailand
Leonics	I	2003	Apricus	China (Australian management)
NTP Techno	I	2004	Rhein Series	China
Siamsolar and Electronices	I	1993	Solarson	China
Thai Advance Save Energy Ltd., Part.	I	2004	NEWGOT SOLAR	China
ARC Siam Solar	I	2005	Schueco	Germany
Century Sun	I, A, M	2005	Century Sun	China Thailand
Forefront Foodtech	I	2006		Denmark
Sunpower Asia	I	2006	Sunpower	Israel
Pro Solar Group		2007		

Note: I: Importer, M: Manufacturer, A: Assembler/Fabricator

Table 1: Compilation of Solar Water Heater Suppliers in Thailand 1985–2006

Future Market size for solar thermal systems in Thailand

A country comparison of installation area per 1000 persons show for the year 2000/2001, that Thailand has a specific value of around 1 m²/1000 persons (so far around 62 000 m²) while China has a corresponding value of 28, Germany of 51 and Israel even 580.

The technical potential for solar thermal systems in Thailand was identified to be substantial, it could be around 2,5% of the total final energy consumption in Thailand in the year 2016. The Table 2 shows the details.

Sector	Number of units	Collector area in m²	Annual Energy saving in GWh
Residential	4,5 Mio. households	9 000 000	5 400
Hotel	3500	350 000	280
Hospitals	1 400	70 000	56
Food industry	106	26 500	21
Textile Ind.	409	265 850	213
Total		**9 712 350**	**5 970**

Table 2: Technical potential for solar thermal systems in Thailand

A realistic target for the market is given in Table 3. It shows, that around 550,000 m² can be installed within the next 10 years. This figures would mean, that the total installed collector area would have to be tenfold within the next 10 years. The annual market growth would be around 27%/a. This development seems to be realistic and achievable, if the government will implement a minimum set of supporting policies, like reduction of import duties and the removal of LPG subsidies, which is actually planned for this year.

Sector in Thailand	Number of units	Collector area in m²	Annual Energy saving in GWh
Residential	200 000 households	400 000	240
Hotel	1000	100 000	80
Hospitals	400	20 000	16
Food Industry	30	7 500	6
Textile Ind.	50	32 5000	26
Total		**560 000**	**368**

Table 3: Estimated market size for collector area to be installed until 2016

POLICY RECOMMENDATIONS

Finally a list of policy accompanying measures that was discussed during the EC SPF project and should be considered to fully develop the solar thermal market in Thailand. It is expected, that future projects and finally the government will pick up these proposals and develop a comprehensive policy.
The activities may be summarized as:

- Financial incentives, either direct or indirect, at least for the most promising and market relevant applications.
- Quality assurance measures. This topic covers
  - Responsibility of a national certification body for the approval of national test centers;
  - Agreement on standards of solar thermal components;
  - Establishment of approved national test centers for the certification of solar thermal system components;
  - Capacity training and qualification of manufacturers, planners and installers;
  - Service and warranty on component and installation level;
  - Evaluation of monitored systems, evaluation of funding programs.
- Demonstration projects, showing the applicability using solar thermal energy in different technical solutions.

- R & D measures, to improve the system and product quality; involving both, research institutes and local manufacturers.
- Awareness rising campaigns, mainly addressed to the end-user.
- Quality conditions of a funding scheme. A funding scheme should be connected with quality measures. Usually, grants are given to systems where certified collectors according to the national valid Standards are applied.

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The Solar Water Heating Market in Australia

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Introduction

The market for solar water heaters in Australia has increased dramatically since the turn of the century when the federal government and a number of state governments began providing performance-based incentives for solar water heater sales.

Fig. 1 illustrates that, historically, the rise in sales is a repetition of the late 1970's when public reaction to the oil price shock increased sales dramatically. A downturn in sales occurred in the mid 1980's due to a combination of low energy prices and some solar water heater failures due to freezing. It was not until 2005 that sales topped the peak experienced in the mid 1980's.

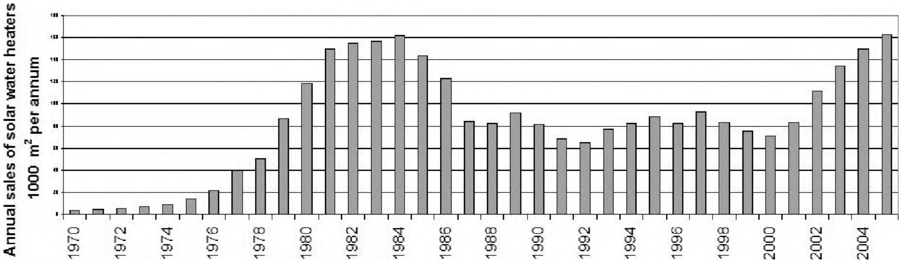


Fig. 1: Glazed solar water heater sales in Australia 1970–2005

Government support plays an important part in maintaining product quality and consumer confidence in the reliability and durability of solar technology as a low environmental impact supplier of hot water. A number of different market support mechanisms are active in Australia, including:

- The tradable certificate scheme that is used by the Australian Government to deliver renewable electricity. Solar hot water systems are included as a renewable energy technology based on the amount of electricity displaced.
- Rebate (subsidy) schemes available in some states.

- State regulations to encourage sustainable outcomes in new homes. For example Victoria, the southernmost state of mainland Australia, has recently regulated a 5 Star Standard for new houses. As well as requiring a minimum energy efficiency level for the building fabric, the regulations require the use of either a solar water heater or a rain water tank.
- Information and advertising to maintain customer confidence and ensure solar water heating is a considered water heating option.

Tradable certificate scheme

The Australian Renewable Energy Certificate (REC) scheme is the means to deliver an additional 9,500 GWh of renewable energy per year by 2010, an estimated additional 2% of the electricity consumed in that year. The Office of the Renewable Energy Regulator (ORER) oversees implementation of the measure through the *Renewable Energy (Electricity) Act 2000* and the *Renewable Energy (Electricity) (Charge) Act 2000*, supported by the *Renewable Energy (Electricity) Regulations*. Details of the scheme can be found on the ORER website [1].

Renewable energy certificates (RECs) are created based on the generation of accredited renewable electricity by renewable technologies, or the displacement of electricity by the installation of eligible solar water heaters. A certificate is equivalent to one MWh.

To simplify the inclusion of solar water heaters and small generation units (PV and small hydro) in the target, the number of RECs that can be claimed for eligible systems has been calculated and agreed by ORER and are referred to as deemed amounts.

Deemed REC values for eligible solar water heater models is included in a list within the regulations. The list is updated approximately twice each year.

Value of REC support

As illustrated in Fig. 2, in 2004 RECs were trading at up to Aus$ 39. A solar water heater typically installed to provide hot water to an average family would be eligible for approximately 25 to 30 RECs. Therefore the REC value per system was around Aus$ 1000. Between March 2005 and October 2006 REC values dropped substantially to about 35% of the peak price reached. [2] The drop in price was caused by the understanding that renewable electricity generators, currently committed to be commissioned over the next few years, will provide most of the RECs required to fulfil current requirements until 2020 (BCSE [3]).

RECs prices have recovered since October 2006. This is thought to result from reduced REC generation from hydro plants due to drought and speculation that the federal government may increase the target.

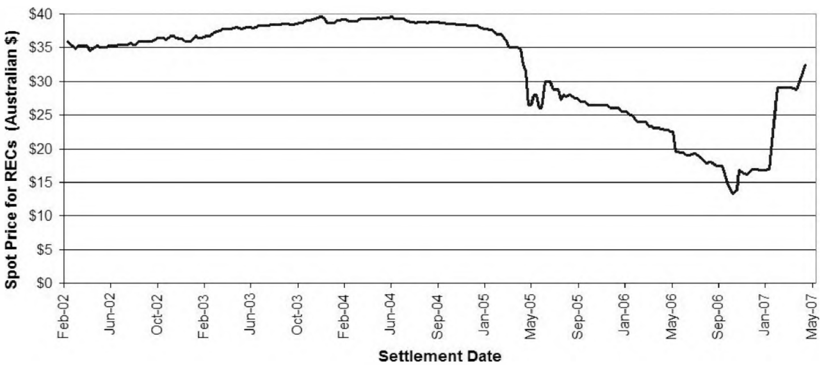
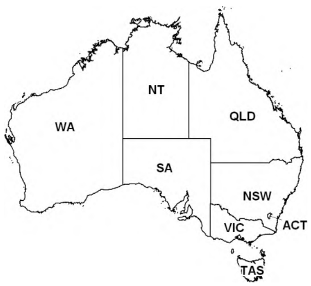


Fig. 1: Glazed solar water heater sales in Australia 1970–2005

STATE BASED REBATES



From 2000 to 2005 most State Governments supported the sales of solar water heaters by providing rebates (subsidies) to the purchasers of solar water heating systems. Queensland (QLD), New South Wales (NSW) and the Australian Capital Territory (ACT) have recently closed rebate programs. The recently elected NSW Government had a pre-election policy to provide again provide a rebate for solar water heaters, which is yet to be implemented.

VICTORIA

Victoria (VIC) has had a rebate scheme for solar water heaters since mid 2000 [4]. This has been very successful resulting in:

- over 10,000 installed systems;
- $ 40 million of sales generated;
- the development of new gas boosted products that deliver very low greenhouse emissions; and
- a fourfold increase in the rate of system installation

A review of the Victorian rebate program found that for households that installed solar water heaters:

- Average energy savings of 54% were achieved
- 91% of householders were satisfied with their purchase; and
- 93% would recommend solar water heating to a friend.

Rebates range up to $ 1,500 for large gas-boosted solar water heaters. They must be replacing conventional gas, wood, briquette or oil fuelled water heaters or be upgrading an existing hot water system to solar.

Replacing a gas hot water heater with an electric-boosted solar water heater does not qualify for a rebate, as the greenhouse reduction would be negligible.

Other States

South Australia (SA) has a rebate scheme that provides rebates of $ 500 or $ 700 depending on the size of the system, $ 700 for heat pumps and $ 500 for retrofits and pre-heating systems. The solar water heater must be installed at the owner's principal place of residence, and, as in Victoria gas replaced by electric-boosted solar is not eligible for a rebate nor is electric-boosted solar on a new house where reticulated gas is available

Western Australia (WA) provides a rebate of $ 500 for natural gas-boosted solar water heaters and $ 700 for bottled LP gas-boosted solar water heaters used in areas without reticulated gas. The solar water heater must be:

- Gas boosted solar
- Private domestic use
- At least a two panel system

New home regulations

A number of states have sustainability requirements for new houses that are driving the market for solar water heaters [5].

Each state has different approaches depending on the greenhouse intensity of the current mix of fuels for water heating and the availability of alternatives. Market results vary depending on the stringency of the requirement and the range of options allowed. For example, Victoria has mains gas available to over 80% of houses and many already use gas for water heating, so gas-boosted solar is desired to further reduce greenhouse pollution. In contrast, in South Australia 57% of houses have gas available and the aim is to ensure that high greenhouse intensity electric resistance heating isn't used where gas is available. These different regulation approaches in different states are summarised below

Victoria

The Victorian State Government has recently enacted regulations to reduce greenhouse pollution and save water in new houses. All new houses and single storey units designed since 1st July 2005 have been required to meet a minimum energy efficiency standard and include one of two sustainability options:

- a solar water heater system; or
- a rainwater tank connected to all sanitary flushing systems

Victoria has required new houses to install insulation since the early 1990's. The wider availability in the late 1990's of computerised tools to evaluate the energy implications of designs at an early stage has also allowed a verification process of building plans for energy efficiency. After a few years experience in the voluntary use of the FirstRate House Energy Rating software package, the regulations were changed to require a more comprehensive analysis of the housing fabric and the achievement of a five star rating on the fabric of all new houses. The five star rating requires houses to be designed to reduce heating and cooling needs to about 50% of the energy requirement of new houses prior to the regulation.

At the same time the plumbing regulations have been revised to include a requirement for a solar water heater or a rainwater tank. These regulations establish the standards required for the installation of solar water heaters. This includes setting the minimum energy saving compared to a conventional water heater at 60%. Initial analysis indicates that about 75% of Victoria's new homes are installing solar water heaters.

New South Wales

New South Wales, Australia's most populous state in has a mandatory building sustainability index, known as BASIX [6], for new houses. This online tool allows flexibility by trading off between different end use options to meet the standard for energy reduction (up to 40% greenhouse reduction), water saving and thermal comfort.

The tool uses RECs as the means of performance differentiation between different models of solar and heat pump water heating products. An initial analysis of house plans approved through the BASIX system indicates that 25% plan to install a solar or heat pump water heater.

Queensland

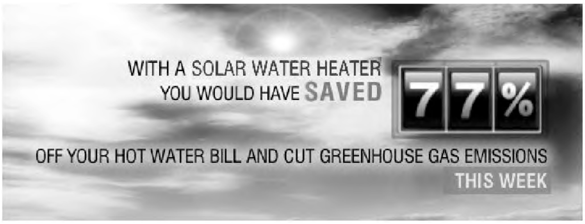
Queensland one of Australia's northern states has over 60% of domestic hot water supplied by electric resistance heating. Recent changes to the Queensland Development Code [7], to reduce the greenhouse impact of water heating have effectively outlawed electric resistance heating in new houses.

South Australia

From 1st July 2006 South Australia has required the installation of solar, gas or heat pump systems in new houses in areas where gas is available. This requirement also applies to any building modification or extension involving changes to the water heater. [8]

Consumer information

In order to increase consumer confidence in the savings available using solar water heaters in Victoria, Sustainability Victoria has launched a weekly solar hot water report, which is available on our website and broadcast on Melbourne television. The report provides an indication of the savings available to an average Melbourne household using a solar water heater, compared to a conventional water heater.



The report uses daily solar energy data supplied by the Australian Bureau of Meteorology to estimate the performance of a typical solar water heater in an average Melbourne household. The correlation of the performance of the solar water heater with radiation levels has been developed from TRNSYS modelling.

The brief television advertisement airs weekly before the weather report on the weekend news and illustrates the dollar and greenhouse savings of solar hot water compared to a conventional water heater, using the simple visual of a rapid count up dial of savings.

The website provides more explanation – year to date estimated performance as well as weekly data is available. The website also outlines the potential impact if all Victorian households had a solar water heater, reported as:

- a percentage of the weekly Victorian Greenhouse indicator for energy from the Climate Group [9].
- the equivalent to taking a number of cars off the road and;
- the number of "black balloons" of greenhouse gas, to tie in with a statewide energy savings campaign that likens 50 grams of greenhouse gas to one black balloon

> **Report for 13 April to 19 April 2007**
>
> If you have a solar water heater, this week you would have cut your greenhouse gas emissions and costs for hot water by **77%**.
>
> And if all Victorian homes had a solar water heater, this week Victoria would have cut its greenhouse gas emissions by **68,000** tonnes. That's the equivalent of taking **822,000** cars off the road this week...or **1.37 billion** black balloons...or **3.7%** of Victoria's greenhouse

CONCLUSION

The solar water heater market in Australia has more than doubled between 2000 and 2005. Approximately 4% of all water heaters now in use in Australia are solar water heaters.

The Australian market for solar water heaters is supported in a number of ways:

- The Australian Government's Mandatory Renewable Energy Target together with state subsidy schemes has driven the increase over the past five years but is beginning to slow.
- States have enacted regulations designed to reduce greenhouse pollution from water heating to address their specific situations. Victoria has enacted regulations that require a solar water heater or a rainwater tank on all new houses from July 2006. NSW, Queensland and South Australia have different approaches that will also provide a significant boost.
- An innovative consumer information campaign in Victoria is providing consumers with performance estimates based on real solar radiation data.

The MRET, state subsidies and regulations provide incentives for the solar water heater industry to develop more efficient and durable products that will maintain a high level of consumer confidence and adoption of solar water heating.

Acknowledgements
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Solar Day: From a national initiative to a European wide event?

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What is Solar Day about?

Between 2002 and 2007 Solar Day has taken place six times nationwide in Austria, four times in Switzerland and twice in Germany. The goal of this event is to increase the presence of solar energy in the media for a short time, raise public awareness through information and advice on site and build up partnerships with other organisations for promoting this event. For one or two days Solar Day becomes a kind of social movement. Throughout the country people have the opportunity to obtain information on solar thermal systems. Manufacturers, suppliers and installers invite the public to an Open Door Day, including company tours and solar entertainment. By information stands, company visits and solar festivals taking place in local communities, the interested public receives independent information and advice on solar energy. In the course of various activities and projects, pupils and teachers explore the concrete possibilities of using solar energy. With the help of an online event schedule, local activities can be found easily.

What does Solar Day achieve?

The Solar Day event is not held in only one place. It is spread all over the country, in numerous local communities, schools and businesses, who participate themselves and promote their activity in the local and regional press. In the course of six Solar Days between 2002 and 2007 thousands of people were involved on location in more than 2,800 events in local communities, companies, schools, energy utilities and information centers in the three countries. The overall number of visitors from the surrounding area was about 200,000. Also media responded to Solar Day with far above 1,000 press releases in magazines, radio and TV quite actively.

Solar Day definitely stimulates local demand for solar thermal systems to be used for domestic hot water and space heating. Those who particularly benefit from the increased demand are tradesmen of the respective community, who earn 30 to 40 percent of the total turnover of a solar thermal system. The increased attention for solar energy by Solar Day has contributed to market development significantly: annual solar market in Austria and Switzerland has doubled since 2002, in Germany even tripled!

Compared to other conventional campaigns, Solar Day is extremely cost-efficient. The basic idea for this campaign stems from the concept of social marketing which uses existing information channels between associations and organisations and their members (newsletters, mailings, newspapers, etc.) to call attention to the event or campaign.

Who organises Solar Day?

Originally the national Solar Day was started in 2002 by the Austrian Solar Industry Association (Austria Solar). Since 2004 Solar Day is part of the market stimulation program "solarwärme" in the framework of the Austrian climate protection programme klima:aktiv. In the year 2004 the Swiss Solar Industry Association (SWISSOLAR) transferred the concept to Switzerland. In 2006 the German Solar Industry Association (BSW) adopted the concept as part of the national solar campaign "Wärme von der Sonne". As a follow-up the campaign focussed on a Solar Week (Woche der Sonne) starting with the Renewables Day on April 28th 2007 until Solar Day on May 4th/5th 2007.

Many co-operation partners have provided their networks to invite communities, schools and businesses to participate in Solar Day, like climate alliance, environmental counselling, business associations, agenda 21 networks. Solar Day is a chance to offer concrete environmental activity to their network members (communities, schools, businesses) with limited effort. The solar industry associations in the three countries collect all informations in an online event schedule and support participating communities etc. with information materials like brochures, folders, posters, banners, T-shirts, videos, samples of articles and letters etc. These materials, mostly free of charge, are delivered by the solar industry associations coordinating Solar Day nationally.

What happens at Solar Day?

Solar Day is spread over numerous events in the country, all organised locally. Some examples of Solar Day events in the different countries:

- Information stands and lectures in communities, at schools and universities
- Public solar exhibition with solar models designed by teachers and pupils
- Kids activities like painting t-shirts, posters, bags, bulk balloon start
- Official opening and guided visits to public/private sites (sports facility, etc.)
- Open Door Day and guided tours with entertainment at manufacture sites
- Local solar fair/solar workshop by installers and environmental counselling
- Guided bicycle tours to several solar systems in a community

Solar Day in a kindergarden in Laab im Walde (Austria)

Solar Day in the community Amstetten (Austria)

Solar Day in the city Dietikon (CH)

Solar Day in the city Basel (CH)

European Solar Day 2008

In order to establish a European Solar Day from 2008 on, an EU project has been designed and submitted to the Intelligent Energy Europe Programme last year. The objective is to expand Solar Day of Austria, Switzerland and Germany also to France, Italy, Slovenia, Spain and Portugal, with new countries gradually joining during the coming years. The European Solar Industry Federation ESTIF will be involved from the start to get into the matter of proclaiming and coordinating the European Solar Day beyond 2008. The project proposal already has been evaluated positively, the project could possibly start this year.

Summary

Between 2002 and 2007 Solar Day has taken place six times nationwide in Austria, four times in Switzerland and twice in Germany. The event is not held in only one place, it is spread all over the country in numerous activities. In the course of six Solar Days between 2002 and 2007 thousands of people were involved on location in more than 2,800 events, with about 200,000 visitors from the surrounding area. Media responded with far above 1,000 press releases. Solar Day is organised by the national solar industry associations, supported by several network partners. The objective is to expand Solar Day of Austria, Switzerland and Germany also to France, Italy, Slovenia, Spain and Portugal, with new countries gradually joining during the coming years. ESTIF should be responsible to co-ordinate European Solar Day beyond 2008.

In co-operation with the planning engineers and the manufacturer of the DEC-plant, optimisation approaches are now being derived which are to be implemented for the cooling period in 2007.

Heat from the Sun – The New Campaign for Solar Thermal Energy

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INTRODUCTION

Solar energy is the energy source of choice of the German population. According to a recent survey by the German Ministry of the Environment, 87% of German citizens want to make a consistent switch to renewable energy sources. However, to date less than 5% of German households use solar energy. The German Solar Industry Association (BSW-Solar) has noticed the great need for information and developed the new campaign *HEAT FROM THE SUN*, which was run in 2005 and 2006 with the support of the German Federal Ministry of the Environment. In 2005, solar initiatives in 30 cities were selected and given intensive assistance in implementing solar promotion events between April and July. In 2006, the number increased to 60.

In 2007, the campaign was developed into the *SUN WEEK*. For the first time, the campaign was opened to all interested parties, while the promotional period was reduced to one week and the topic of solar power was added. Throughout Germany, local solar and agenda groups, craft companies and energy consultants, local authorities, business investors and all other interested parties are invited to hold events related to solar thermal energy and solar power between April 28th and May 6th 2007. Their goal was to provide information locally on the options and advantages of solar energy technology and motivate the citizens to use environmentally friendly solar energy. The first time round, *SUN WEEK* became the largest solar energy campaign ever organised in Germany.

COMPREHENSIVE EXPERIENCE WITH SOLAR CAMPAIGNS

National solar thermal energy campaigns have been run in German for eight years. The first campaign was called "Solar – na klar!" and ran from 1999 to 2001. It was a breakthrough for solar thermal energy in the public eye and for tradesmen. The great solar thermal energy boom which lasted until 2001 was also a result of this campaign. In 2003, the "Solarwärme plus" initiative was launched. This campaign focused on nationwide public relations work and appealing to tradesmen. It placed a particular emphasis on the combination of modernising heating systems and solar thermal energy.

The German Solar Industry Association developed a new type of campaign. In many cities and communities in Germany, citizens have combined to form solar initiatives and agenda groups, and work locally to promote the spread of solar thermal energy. With the *HEAT FROM THE SUN* campaign, BSW-Solar for the first time systematically supports local and regional initiatives with expertise and materials, rather than directly addressing citizens and potential users of solar energy.

In 2005, the first call for tenders was held, in which regional solar initiatives could apply to take part in the promotion. 30 solar initiatives were selected and actively supported in implementing several information events between April and July 2005. In 2006, the number of initiatives increased to 60. The initiatives were supported with a variety of materials, foremost of which were a solar thermal energy newsletter and a solar thermal energy poster exhibition. Organisational expertise in the form of press releases, checklists for the implementation of successful events, presentations etc. was also provided. In order to obtain as broad acceptance as possible, BSW-Solarencouraged the initiatives to form local action alliances. In 2006, more than 700 partners were involved in the 60 initiatives and over 500 events were held between April and June 2006.

The evaluation of the campaign brought the following results:

High local commitment

There is a great potential of voluntary and professional participants in the communities who work to bring about the energy revolution. These participants were supported and assisted effectively with targeted measures.

Creative implementation

There was a wide variety of local events. In addition to information events and info booths, there were solar festivals, solar bicycle tours, plant open day, balloon promotions, regional trade fairs and many more.

Great synergy effects

Centralised production of the professional promotional material resulted in great synergy effects. On one hand, this guaranteed a consistent high level of the materials and on the other, a regionally-adapted edition of the campaign magazine was made available for the participants.

Great reduction of workload of participants

Integration in a professionally supervised campaign greatly reduced the work load of the local workers. The participants, who generally work on a voluntary basis, have limited resources and were therefore highly grateful for the support.

High credibility of the participants
The initiatives have a high level of credibility in the communities and with the citizens due to the idealistic motivation of their commitment.

The campaign was well received by the participants and showed that the effectiveness of the activities of regional participants can be significantly increased by providing professional materials and expertise. However, it must also be noted that individual support of the initiatives is relatively labour-intensive and the resources of the local participants, many of whom are volunteers, are limited.

SUN WEEK

28. April - 6. Mai 2007
WOCHE
DER SONNE

Campaign logo SUN WEEK

Based on the experience with the *HEAT FROM THE SUN* campaign, the German Solar Industry Association developed the *SUN WEEK* initiative. The reason was the desire on the part of the solar companies and the German Federal Environment Ministry, who financed the campaign jointly, to expand it significantly to achieve more market relevance. For this, the following adjustments needed to be made to the previous concept:

- Only highly committed initiatives are able to hold a series of events over several months. In order to activate a significantly higher number of participants locally, the period was reduced to one week in which one or more local events were to be organised.
- Participants cannot be individually supported if the number of participants is significantly increased. For this reason, a standardised range of support measures was created which could be availed of largely automatically via the www.woche-der-sonne.de internet portal.

On this basis, the 2007 campaign was consistently expanded to the *SUN WEEK*, this time incorporating the POWER FROM THE SUN area in addition to the *HEAT FROM THE SUN* area. Thus, for the first time all participants interested in holding events on solar thermal energy and solar power throughout Germany were able to be involved. The combination of events in one week also attracted a great deal of attention for solar energy.

The strength of *SUN WEEK* is to permit maximum flexibility of the participants and events. It is aimed at voluntary initiatives, solar and agenda groups and private system operators, as well as professional participants such as tradesmen, energy consultants or solar companies. Local authorities, management consultants, energy agencies, banks or schools can be involved actively. They can either organise individual promotions or cooperate and organise joint events. There are no limits to the variety of events: Solar festivals and lectures, open days by tradesmen and solar energy system owners, solar walks and energy tours or solar days in schools were held. The local events are intended to reach broad strata of the population, home owners and builders, children, young people and adults, interested parties from the private, commercial and government sectors.

The secret to the success of the *SUN WEEK* is the combination of personal contact via the local participants with the professional support from the project. The efficiency of the local events is significantly increased by the appealing materials. The *HEAT FROM THE SUN* campaign has shown that this concept works.

Increasing knowledge about solar energy

Selling solar energy systems is more difficult than informing customers on boilers or bathroom fittings. This is due to the fact that far more needs and interests are involved with solar energy. Solar energy systems are purchased because customers want to reduce their dependency on oil and gas, because they want to contribute to protecting the environment and climate, because they want to be less open to the effects of increasing energy prices, or simply because they want future-oriented heating technology in their building. Thus, both idealistic and economic reasons are involved in the decision, and fears on the long-term supply of energy play a part.

There are also various alternatives. Customers must decide whether to purchase a solar thermal system or a solar power system, if they want to install a pellet heating system or a heat pump with the solar heating system, whether solar energy systems retain their advantages if this is the case, if they prefer to insulate the roof and facade at the same time, or whether to simply replace the oil or gas boiler. Or, as a result of the many questions to be answered, should they wait until the boiler breaks completely and solar energy systems are less expensive. At the same time, customers must consider available financial aid and the combination of investments which receives most funding. For example, whether the subsidies for solar thermal systems are more attractive than the low-interest loan provided by the KfW bank for thermal insulation combined with a solar system.

Increasing knowledge about solar energy

Thus, this is a complex decision for interested parties. This is the starting point for *SUN WEEK*. The campaign magazine and the exhibition answer all questions related to motivation, fundamental technology, and financial aid. They explain why it is important to switch to renewable sources of energy and the advantages of solar energy. They illustrate the potential options of using solar energy, and the applications best suited to each particular case. They demonstrate attractive examples of implemented systems and give an up-to-date overview of subsidy programmes. The material accomplishes this in a professional, easily understandable and manufacturer-neutral way, which makes them particularly credible.

Efficient and transparent organisation

SUN WEEK is to be held annually in future. This year, 300 participants were expected. However, 1600 events were actually organised by over 1000 participants. This represented an overwhelming result which was not expected in the first year. Such a large number of participants must be supported efficiently, which is why a significant part of the organisational work was done via internet. The participants register independently under www.woche-der-sonne.de and announce their events. The participants and their events appear in the calendar and map of events immediately after they are entered.

The automated entry system allowed BSW-Solar, solar companies, the participants and potential visitors to maintain an up-to-date overview of the status of registration and the events planned at all times. The registered participants are able to change the data they entered, enter new events and correct entries, as well as order promotional material upon entry of a password.

The website also provides sample press releases, sample events and other aids for download. The event calendar of all dates announced nationwide also served to advertise events, as citizens interested in the subject could find out about events in their area.

Professional material


Herausgeber: Bundesverband Solarwirtschaft e.V.

Zeitung für Solarwärme

Informationen der Aktion WÄRME VON DER SONNE zu modernem Heizen

Ausgabe 2007

Grußwort

Solarwärme für alle Haushalte

Marktwachstum hat sich 2006 deutlich beschleunigt

Überreicht durch

WÄRME VON DER SONNE

Woche der Sonne gestartet

Akteure aus ganz Deutschland engagieren sich

Übersicht

Campaign magazine photovoltaic

The most important element of the information material is the campaign newsletter. A solar thermal energy magazine and a magazine on solar power were produced in A4 format. Each comprised 8 pages and had a print run of 400,000 copies. Written and illustrated in an easy-to-understand and varied newspaper style, they encourage readers to use solar energy by offering information on climate change and power supply problems, the potentials of solar energy, the options for the use of solar energy and the technology, financial aid and suppliers of solar energy systems.

The campaign magazine is supplemented by an attractively designed poster exhibition with 12 posters on solar thermal energy and 12 posters on photovoltaics intended for interested lay people. The facts on climate change and the risks of energy supply are explained in an appealing design. Sample systems and photos illustrate the options for using solar energy and the most important terms of the technology. Finally information on financing and subsidy programmes round off the A0 poster series. The high-quality exhibition is designed to be shown in exhibition rooms of tradesmen's companies or in public spaces such as town halls or banks. The exhibition opening ceremony is an opportunity to involve local celebrities and invite the press.

Poster exhibition Solar Thermal Energy

In addition to the information material, *SUN WEEK* primarily offered support for local event advertising. After all, the goal was to attract as many visitors to the events as possible. For this, advertising posters were provided in two sizes, A1 and A3. The posters had free spaces in which the event announcement could be written or printed. Also press material was provided for the local editorial teams. In addition to the sample press releases, there were also press kits with background information on *SUN WEEK*. In addition, checklists and tips for optimal press work were provided.

Participation made easy

SUN WEEK is aimed at all interested persons throughout Germany. There was no limit – all interested parties could take part. The requirement was that one or more local events were held under the *SUN WEEK* motto between April 28th and May 6th. Participation was free and the material was provided at no charge.

Conclusion

In the *HEAT FROM THE SUN* initiative, an entirely new type of campaign was developed which, for the first time, was not aimed directly at end consumers, but effectively supported local participants in addressing end consumers. The *HEAT FROM THE SUN* campaign was organised in 2005 and 2006 in 30 and then 60 cities and regions with great success. At the same time, it also became clear that nationwide expansion would require adaptation of the concept.

Based on the experiences with the *HEAT FROM THE SUN* event, the concept for *SUN WEEK* was developed. This campaign was run for the first time in 2007, and proved to be an overwhelming success. 1600 events were held in over 1000 cities and communities. For the first time, the topic of solar power was included in addition to solar thermal energy.

The local events were supported by campaign magazines on solar thermal energy and solar power. Furthermore a poster exhibition on solar thermal energy and/or solar power consisting of 12 A0 posters was provided to every participant free of charge.

SUN WEEK proved to be an extremely effective campaign format, which is the result of all experiences gained in campaign work over the recent years. It uses the synergies of comprehensive public relations work at a national level with a variety of regional solar events effectively supported by professional material. Compressing the campaign to a week guarantees great media attention and makes it easier for all involved to calculate the effort required.

This year, over 1600 events were held throughout Germany. In the years to come, the number of promotional events is to increase further. Austria and Switzerland act as role models in this, as they have organised Sun Days for the past 6 years. This year's event will be on May 4th/5th. In Austria, over 400 participants took part. If this was extrapolated to Germany, the number of participants would be 4000. This shows the great potential in this type of promotional campaign.

"Solarwärme" – Impact of the Austrian market stimulation program

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Introduction

In 2004, the market stimulation program **solar**wärme was launched in the framework of the Austrian climate protection program "klima:aktiv".

The program was designed to enlarge the already comparatively high penetrated Austrian market. Its initiation and execution is achieved by a comprehensive consortium of marketing and technical experts represented by the coordinating AEE INTEC, arsenal research and the Austrian solar association Austria Solar.

Being a program supported by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management and the Austrian solar industry the overall objectives are to give an important impulse to further enlarge the solar thermal market in Austria and subsequently to reduce CO_2 emissions significantly. The program runs for 4 years and is budgeted with about 3 million €.

Significant impacts indicated after two years of program enforcement

Since many years, Austria is amongst the countries with the highest solar thermal capacity penetration per capita worldwide. After rapid growth of the market in the early 90s, the market experienced stagnation at a high level around the millennium. To counteract this stagnation, equipped with strong national industry and research institutes, new impulses were to be set. It was observed that a special focus had to be put on quality assurance and the development of demanding new market segments (combisystems in single family houses, multi family houses and tourism sector). The central objectives at the start of the program were set as following:

– Trend reversal of stagnating annual installation rates of about 120 MW_{th} (170,000 m^2 collector surface)
– Facilitate market segments with high potential and little penetration so far (combisystems in single family houses, multi family houses, tourism sector)

- Building up and support of an active network of solar thermal competence with multipliers such as energy advisers, consulting engineers and local energy agencies
- Enhancement of the quality standard on the domestic market by a broad training program for plumbers, planers as well as energy advisers, the enforcement of planning audits and strong technical feedback to the solar industry

After two years of work, the programs' prosperities can be clearly seen in the Austrian solar thermal statistic. With 210 MW_{th} (300,000 m^2) installed in 2006, the determined goal of boosting the stagnating market to a level of annually 140 MW_{th} (200,000 m^2) by 2008 was by far outreached already after half of the program duration. As Fig. 1 presents, the market showed significant increase since the start of the program and according to this ESTIF statistic, in 2006 Austria repeatedly shows up with the highest per capita installation rate in Europe.

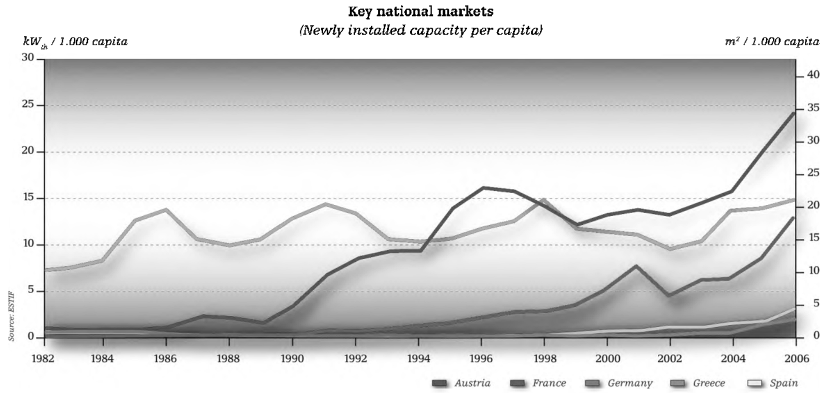

Fig. 1: Annually newly installed capacity per capita (Source: ESTIF)

Factors of success

Looking at its balance of activities after 2 years of work, the **solar**wärme program can be ascribed a significant responsibility for the positive development especially in the new market segments. The project team succeeded in achieving high acceptance to the relevant multipliers. Initiatives in the allocated critical fields of action, information and motivation of investors, know-how transfer to professionals and enhancement of quality were set and received with high acceptance:

- 80 special events for professionals and end customers
  A total of 5,500 visitors could be welcomed at special events. The scope of the events reached from a mainly motivational character for stakeholders as single

family house owners or tourism managers to planning workshops for professionals.

- 300,000 page views of the new program website www.solarwaerme.at
  The program brought out the most extensive Austrian internet resource for solar thermal issues was created with special areas for the target groups single family houses, multi-family houses, tourism sector and professionals.
- 90,000 information brochures distributed to the target groups
  Independent information brochures individually designed for the relevant target groups were designed and disseminated via events, energy agencies, professionals and federations.
- 3,000 enquiries at the solarwärme telephone-hotline
  An independent service hotline was implemented to provide stakeholders with information on all kinds of issues connected to the use of solar thermal.
- Over 600 participants at specialized training
  50 technical trainings were offered to professionals and consultants in the field of solar thermal. The national quality brand "Certified solar thermal plumber" respectively "Certified solar thermal planner" was created and successfully introduced to the Austrian market.
- Establishment of an efficient network of 1500 partners
  A lively network of partners (guilds for installers, planners, architects, chambers of commerce, companies, educational institutions, etc.) for the organisation and promotion of the program activities could be consolidated.
- Initiation and support of 5 additional federal solar campaigns in Austrian federal states
  Representing the high acceptance of the campaign to multipliers, five additional federal solar campaigns mainly in cooperation with local energy agencies were initiated resulting in a number of events and trainings as well as the creation of beneficial frame conditions for solar thermal market growth

Highlights and perspectives

Amongst the numerous activities within the **solar**wärme program a number of highlights point out, reflecting the benefit of the strategy to focus on quality assurance and new market segments.

Especially the launched training initiative proved to be of high importance and big success. The efforts foreseen for this part of the program were by far exceeded because of the enormous demand from professionals and the domestic industry. Another striking example for the impact of the program is the growth of annual installations in the tourism sector. From 2004 to 2005 the annual installations could be nearly tripled and are expected to experience further growth in 2006. Just in the tourism sector, 14 MW_{th} (20,000 m² of solar thermal collectors) were installed in 2005.

The legislative achievements in Styria serve as an example for the successful lobbying activities for new market segments. Not only is the installation of a solar thermal systems now a prerequisite for gaining subsidies for the construction of dwelling buildings, but also technical instructions for the optimised design and dimensioning of collective solar thermal systems for multi family houses could be anchored in the subsidy order to achieve a high standard of quality of the solar thermal installations.

Continuing the settled direction of activities, the program team has pointed the way for further significant contributions to the positive development of the Austrian solar thermal market.

Strengthening the technical frame for large scale solar thermal installations design and maintenance through the Guarantee of Solar Results' (GSR) quality approach.

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Introduction

Solar thermal is clearly considered as a mature technology which could contribute to GHG emissions reduction and energy independency. It can potentially be used everywhere and for different applications such as domestic hot water production in individual or collective systems, combined solar systems, solar cooling or air conditioning and swimming pool heating. In this significant market and despite a small percentage, large scale systems provide relevant examples of good practices with positive outputs on the whole solar field. On the contrary, due to the high visibility of those installations, bad examples can have a harmful impact on public's perception and slow down this growing and promising market's development. This is why a particular attention must be paid to products' quality, the way installations are sized and designed and their performance follow-up during their operation.

Regarding the European installed surface (2 Mm2 in 2005), and despite a growing market, the repartition is still unequally distributed with a significant development in some countries which are not the sunniest ones. This means that many other factors have to be considered for a structured and increasing market.

After having explored lessons learnt from the past European experience and summarised success factors and barriers, the relevance of a quality approach and more especially of the Guarantee of Solar Results (GSR) will be underlined. Significant examples of EC supported programmes will illustrate its effectiveness in the market structuring process. Ongoing analyses and needed evolutions will be shortly presented and some recommendations for a scale-up effect will be proposed as a conclusion.

The European solar thermal market: success factors and barriers

A contrasted situation throughout Europe…

If Europe is clearly one of the leading regions of the world in terms of installed solar capacity, this results from a several decades experience and a proven technology. Though, with approximately 16 Mm2 of solar thermal collectors operating at the end of 2005, Europe is actually far from reaching the objectives set in the 1997 White Paper which refers to 100 Mm2 by 2010.

This sector's average growth was significant in 2005 with an increase rate of 26% but an in-depth analysis reveals a much contrasted situation among countries. Leaders are Germany (approx. 6,5 Mm2), Greece (3 Mm2) and Austria (2,3 Mm2) representing all together more than 74% of the total installed capacity. Some other countries have promising markets such as France, where the growth rate was up to 134% in 2005 and which could play a major role in Europe if the current support schemes are implemented in a long term perspective.

… revealing common barriers and success factors

Such differentiated situations, and more particularly considering that Austria and Germany, that are obviously not the sunniest countries in Europe, have reached a well structured solar thermal market, indicate that key success factors and barriers are mostly independent from climate conditions.

The existence of proactive regulations, such as building codes and/or stable support mechanisms, is a key element observed in all growing national markets. It counterbalances the fact that positive externalities are usually not enough reflected by conventional energies prices and in investors' costs/benefits analyses. It is also needed to work on harmonised standards and labellisation for equipments and components. In that sense, the "Solar Keymark" quality label launched in 2003 is a good example of an European initiative. In addition, awareness raising campaigns addressed to decision makers and general public are of great relevance, as well as demonstrative pilot projects which also contribute to a better public and professional perception. Finally, support to qualified and motivated professional networks also represents another powerful tool.

This short overview reveals that incentives as well as harmonised and supportive policies have to go close together with systems improved reliability.

A quality approach concept to structure the solar thermal market

The necessity of a transverse approach: learning from the past

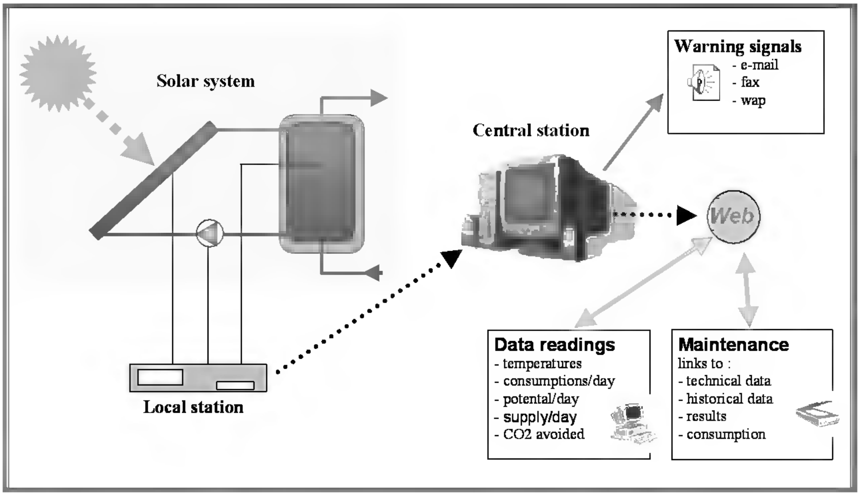
In most European countries, solar thermal market's development started in the late 70's consequently to the energy crisis. At the end of the 80's, various audits led on collective solar installations revealed high failure rates. Quality problems were related to low quality collectors, complex and/or badly dimensioned systems, poor quality of execution and deficient maintenance. As clearly illustrated in the French case, end-users and building actors' lack of confidence became a blocking point toward solar market. This highlighted the necessity to both secure the systems' productivity and minimize the risks for the users by a transverse quality approach leading to:

- quality products – i.e. recognized by official labels and standards- for foreseeable performances,
- trained professionals in order to size, design and realize the installation properly,
- guaranteed maintenance and developed after-sale services.

Such a transverse approach is a key element to structure the whole market: project risk is reduced, project holders are secured, possible financers are less reluctant to invest and public subsidies are more efficient. If the price component is important in the sustainable solar thermal market's development, it has limited impact without confidence and visibility on the project pay-back time which are core elements of the particular Guarantee of Solar Results (GSR) quality concept.

The Guarantee of Solar Results approach or how to involve the concerned actors

The GSR is a five year contract which guarantees an annual quantity of solar–produced energy calculated on the basis of mutually agreed water consumption. The Guarantor is a joint consortium gathering all operators taking part in the project implementation: the engineering and design department, the fitter, the manufacturer and the company in charge of the maintenance. Responsibilities are distributed between members according to a temporary grouping convention. At the end of the contract, if the cumulated guaranteed energy is not reached, the Guarantor will have to compensate the building owner on the base of the missing part. Within the first year, the consortium has the possibility to modify the installation if needed. The obligations resulting from the contractual commitments reinforce in a way the sense of responsibility of the professionals involved. From a financial point of view, risks are minimized since the service is guaranteed by a contract which clearly mentions compensations. As a consequence, loans or public subsidies are more easily mobilised.



Solar system supervisor

Up to now, the GSR procedure has been dedicated to the largest collective plants mainly because installations' real performances have to be measured using monitoring equipments, which implies additional costs. However, such approach has positive effects on the whole solar thermal field as products and techniques are largely similar for both large and small scale installations.

Finally, a recent French market survey has pointed out that cases of non-observance of the GSR contract are very rare. This is a continuous virtuous circle.

Encouraging experiences from France to Europe and abroad

Transposition of the French experience into other European countries with EC support

The GSR has been first developed in France by professionals of the solar sector and with the support of ADEME (the French Environment and Energy Management Agency) in response to the above mentioned difficulties of the late 80's. Market's development was refocused on users' satisfaction. This led to the implementation of a quality approach in all solar thermal sectors and particularly thanks to the national "Plan Soleil" (1999–2006) launched by ADEME. At this time, with regard to collective installations and in order to have access to subsidies, three prerequisites had to be fulfilled:

- the installation had to be implemented according to the GSR procedure,
- technical Agreement was needed for solar collectors,

– installers had to attend training sessions or to be co-opted by recognized professionals in the framework of the "Qualisol" network.

Recognizing the GSR approach's positive impacts on the market, EC has supported different projects on this topic. The main issue was to adapt the administrative rules and procedures to each national context. The transposition of the GSR French original model was thus achieved with differentiated levels. It has to be underlined that, despite the fact that only few realisations using the GSR contract exist in Europe (Austria, Denmark, Netherlands, Greece, Spain and Germany), most markets were structured based on a similar quality approach.

Regarding future potential application, the French Energy Savings Certificates mechanism (EEC or White Certificates) can open new interest for the GSR contract. For collective solar thermal application, EEC calculation requires signature of one GSR contract in order to have detailed annual data on energy saved which means CO2 avoided. Other countries, as Great Britain and Italy, are also developing such certificates with encouraging results.

A Mediterranean transfer, the MEDA ASTEMB project example

The "Applications of Solar Thermal Energy in the Mediterranean Basin" project co-financed under the MEDA Program was implemented between 2001 and 2004. Based on European experiences, the topic was to transfer the GSR quality approach in 7 Southern and Eastern Mediterranean countries with a significant solar thermal potential. The GSR quality approach was adapted to the national contexts and pilot projects were tele-monitored. The point was also to work on certification processes, identification and recommendations on appropriate support schemes. In each country National Plans for solar thermal applications were elaborated. Dedicated training workshops were also organised in order to consolidate professional knowledge.

Orphanage – Lebanon – Dar el aytam (photo Pierre Zabbal)

The objective to reach was to contribute to the emergence of an autonomous and sustainable solar thermal market in the region with competitive national industries and reliable professional networks. Even if this objective is a long term one, it has to be underlined that in the concerned countries a real national interest has followed the project implementation. For instance, in Tunisia, for large scale installations, GSR is now a prerequisite to get access to national subsidies.

Information on the project and the different publications are accessible on the project website: www.solarmed.net.

Promoting the quality approach in Eastern European countries: the EAST-GSR project ambition

Started on January 1st 2006, EAST-GSR is a 36 months project coordinated by ADEME and co-financed by the European Commission within the framework of the ALTENER program. The objective is to support the emergence of a sustainable solar thermal market taking advantage of the GSR quality approach. Concerned countries are Bulgaria, Poland, Romania, Slovak Republic and Slovenia. Experiences from Austria, France, Germany and Greece will help this process. For those five countries, developing their renewables market is of the utmost importance to contribute to the overall European objectives.

An in-depth analysis of national situations already allowed gathering data on national energy markets, with a special focus on the solar thermal one. The listing of existing legal and institutional frameworks also helped identifying the solar thermal market barriers and potential. Economic analyses and requirements are on process and a very detailed list of stakeholders has been elaborated (officials, professional associations, universities, industrials, distributors, etc), with a particular focus on housing and tourism sectors.

The GSR warranty contract will be soon adapted to national contexts and translated in national languages. In each country, one existing collective large-scale solar installation has been selected and will soon be equipped with a tele-monitoring system for demonstration purpose. Simulation of GSR contract will be implemented on each one.

Knowledge transfer is also a key issue and data collected from the tele-monitored installations will be used for training purpose. In parallel, pre-feasibility studies will be conducted on potential new installations. These case studies will be disseminated as widely as possible in order to attract new potential investors, owners and even financial institutions.

Proactive networking and dissemination activities are strategic aspects of the project as the overall topic is to demonstrate that this technology is a mature and attractive one. The expected result is to contribute to the market development based on a quality approach concept. Information and documents on the project are accessible on the project website: www.solareast-gsr.net.

GSR quality approach future development and scale up effect expectation

Adapting the technical procedures to a broader type of collective installations

An ongoing assessment of ADEME's French "Plan Soleil" enables to outline significant results on quality approach experience feedback. Originally, GSR was mainly dedicated to systems over 50 m² collectors' area, meaning that the majority of collective systems for DHW production which are smaller than 20 m², were not undertaken under the GSR procedure. Keeping in mind that medium size installations represent a significant proportion of the installed surface, and regarding monitoring needs, the objective is now to create conditions for a broader application of the GSR approach.

Cost remains a key factor. Remote telemonitoring is clearly appropriate for larger installations (more than 50 m²) and light data controller, even manual ones, can be used for smaller installations. In each case, the layout and the procedure have to be as simple as possible in order to be easily used even by the owner if he is associated to the data acquisition process.

The French survey has pointed out that a significant part of malfunctioning was due to oversized installations. In addition to investment cost reduction, such problems can be easily overcome thanks to the monitoring approach.

Nowadays, and despite increasing data measurement precision, many professional argue in favour of lower guarantee's threshold. The current one (90%) being considered by many as too severe and non realistic considering topics to be measured, a reduced one would be much more acceptable for professionals and would change nothing for end users (the productivity of a defective installation is included between 0% and 20%).

A quality approach to be considered not as time and money consuming

Simplified GSR procedures allow reduced costs while maintaining a high performance level. It makes possible a better contractual flexibility in terms of distribution of responsibilities between professionals and the building owner. For instance, the owner can get involved in the measurement process and be in charge of transferring an alarm to the maintenance service company. In that case, the monitoring equipment can be a manual and less expensive one, even if more sophisticated systems with external monitoring remain possible. A key point is to adapt the complexity and the costs generated by the contract (and the required equipments) to the size of the installation.

More generally, the procedure could take advantage of a better consensus between all involved partners. For instance the contractual period might be extended to more than the current 5 years if both building owner and professionals agree on it. Besides, penalties are not a compulsory element of the contract.

In fact, many ways to implement a quality approach, from regulatory means to market incentives exist. Without being exhaustive, we can point out the interesting ESCO experiences such as the Solar Contracting one where the whole quality process is of the utmost importance since the profitability of the external energy provider is linked to the system performance optimisation. Obviously a quality approach is often a mix of both components.

Conclusion

Throughout French, European and other countries relevant examples, we have noticed the great importance of the quality approach in the whole solar thermal market's structuring process. This overview shows that growing markets are structured by a convergence of factors; among others, a consistent regulatory framework, quality mechanisms such as certifications or labellisation, involvement of local and national authorities to increase promoters' and public awareness ... The French experience in the 80's has highlighted that without a whole quality approach, bad examples can easily create long term negative effects.

The GSR contract, by involving all concerned stakeholders, and creating mutual commitment, can contribute to the expected scale-up effect on the solar thermal market.

After having demonstrated that this approach is helpful for large installations, the objective now is to work on its application on smaller and, in the future, even individual ones. Cost consideration will be a key issue, but moreover, simplified options or more flexible ones can positively help market process. In each case, this will have to be adapted to the market state of development. For example, in European Eastern countries, where the process is more or less at an early stage, the GSR quality concept approach in its original version can certainly support market development.

Finally, it has to be underlined that all support mechanisms, both on a regulatory or voluntary base, have to be coherent and properly arranged in order to be enough attractive for investors and owners. Regarding climate change issue, it has to be mentioned that the performance monitoring will be more and more a strategic issue and for that purpose GSR approach can certainly provide good experiences analyses.

Solar heating systems for multi-family houses. Keep it simple!

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Introduction

The development and implementation of collective solar thermal systems is gaining importance. The European project SOLARGE (enlarging solar thermal systems in multi-family houses, hotels, public and social buildings in Europe) running till December 2007, incorporates all relevant aspects. One of the promising target markets analysed in 8 EU project countries is the Multi-Family Housing (MFH) sector. Not only because of the large number of buildings but also due to (new) legislative issues. The application of solar thermal systems solutions in this market is not uniform and a lot of technical as well as non-technical issues have to be addressed. This paper will give an overview of the MFH market as well as the main different system configurations including an analysis on technical issues: e.g. system performance, complexity and reliability, system heat losses, etc., as well as on non-technical issues like investment costs, ownership, exploitation and invoicing and maintenance.

MFH solar thermal market

Based on the market figures of the SOLARGE project (Sievers, 2005) and some expert guesses an initial estimation of the MFH solar thermal market was made for the 8 participating countries. The total estimated annual potential is 820 MW_{th}, this is 15% of the total accumulated installed capacity in these countries. The annual energy production of this potential is 475 GWh, which will reduce 210 Mtons of CO_2 on a yearly base. The potential is roughly divided in 60% existing and 40% new build MFH. Currently Spain has the highest annual potential, around 350 MW_{th}, followed by Germany and France with 150 MW_{th}. The overall potential in Spain is mainly focused on newly build MFH. The reason for this is that from 29th September 2006 onwards, it will be obliged to apply solar thermal systems in all new buildings and major renovation projects, in combination with a remaining high building volume. (Voskens, 2006)

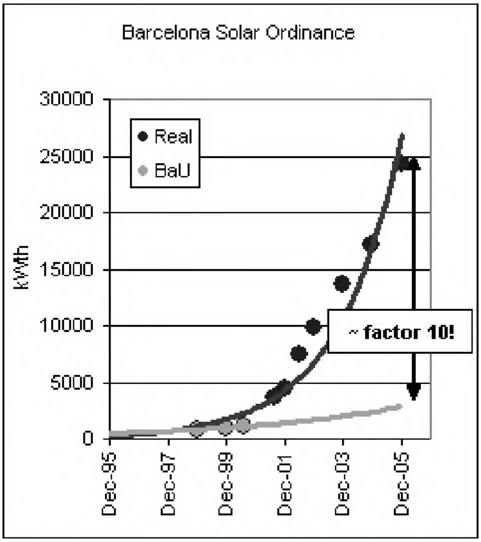


Fig. 1: Acceleration effect of a solar obligation. Accumulated installed kWth solar thermal systems in Barcelona (real) against the Business as Usual scenario (BaU).
Source: Energy Agency Barcelona

Solar obligation: Barcelona factor 10!

Barcelona was the first European city that adopted successfully a solar obligation from 2000 onwards, see Fig. 1. Since then dozens of other cities copied the model. Further more the Barcelona Solar Ordinance served as well as a model for the solar obligation in the region of Catalonia and for the Spanish new building code (CTE). Currently several other regions and countries are studying this model to apply. Important issues for a successful implementation are: quality control, capacity building & training and dissemination.

System configurations

Solar powered hot tap water installation

Solar thermal installations are mainly used for the production of hot, sanitary water. In this paper this main application is considered. The 2 main components of a solar powered hot tap water installation are: the solar thermal system and the back-up heater. The solar system itself is normally formed by 2 main components: the solar collectors, transferring the solar irradiation into useful solar heat and a storage tank to store the solar heat for later use. Some systems combine the solar/hot water storage and the back-up heater in one device and some systems combine collector and solar storage in one device (so called Integrated Collector Storage). Because the working fluid of solar powered hot tap water installations is liquid (water based) the components are connected by tubes to transport the energy from one component to another. We distinguish 3 main circuits: primary circuit, between collector and solar storage, secondary circuit, between solar storage and back-up heater and a third circuit between back-up heater and demand (taps). For the final savings these circuits have to be taken into account because of heat losses, especially if recirculation circuits are applied.

Different system configurations

For solar powered hot water systems several basic system configurations exist. The main distinction is between central versus de-central components (collector, solar storage and back-up heater). On this basis we can describe 4 main configurations (see Table 1 and Fig. 2). The gray-shaded areas are not applicable.

Collector	Solar storage		Back-up heater		Number	Remark
	Central	De-central	Central	De-central		
De-central*		X		X	1	Single family houses, apartments buildings up to 2 or 3 storeys
Central*	X		X		2	Large central systems (e.g. hotels)
	X			X	3	Large systems for multi-family buildings
		X		X	4	Large systems for multi-family buildings

Table 1: Basic system configurations
**) de-central is on dwelling level, central is on string or building level*

In principle, for the MFH sector all main configurations can be applied. Totally centralised systems (2) are essentially the same as configuration 1, although all components are larger. If this configuration is applied for MFH normally a hot tap recirculation circuit is incorporated in the installation design for comfort reasons (less waiting time). System configurations 3 and 4 are specially developed for multi-family buildings. The systems have a central collector, a de-central back-up heater and a central or de-central solar storage. The applied back-up heater can be a flow through combination boiler (for heating and hot tap water), or a hot tap water storage heated by electricity or a conventional boiler/fuel. Configuration 4 can be divided in different sub-configurations (see Fig. 3):

4.1) Solar storages connected in parallel (per string of building) with 1 central solar control unit and pump

4.2) Solar storages connected in parallel (per string) with de-central (1 per dwelling) solar control units and pumps

4.3) Solar storages connected in series (per string) with 1 central solar control unit and pump.

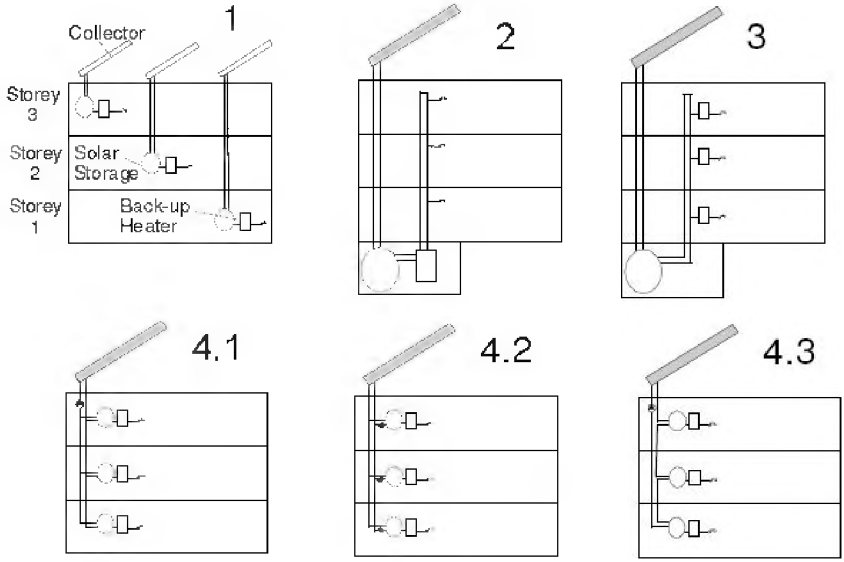


Fig. 2: Overview of analysed system configurations for MFH

Analyses

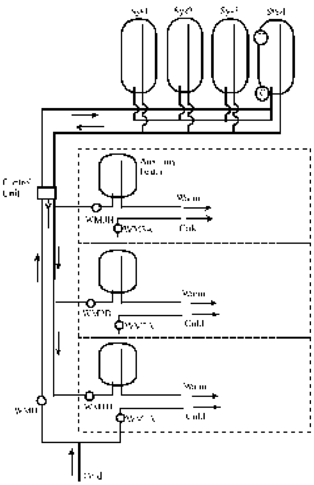
In Table 2 the considered system configuration are analysed on main technical issues: suitability, system performance, system heat losses and complexity and reliability, as well as on non-technical issues: like investment costs, exploitation and invoicing and maintenance.

Which configuration is the best solution will be determined by various conditions and sometimes dictated by the building and/or existing installation. Also the various actors will have different needs. End users want to have a reliable hot water supply, low energy bills and no maintenance. Property developers will normally look for the cheapest solution which complies with the minimum requirements. Also occupied floor area by a solar system (= losing money) is an issue for them. However, in general the total market and all actors are served best if systems will be applied that will deliver solar powered hot water over 20 years without technical problems and a minimum requirement of maintenances. This is especially true for solar powered hot water systems because of the classic problem that in the case the solar system fails this will not (directly) be noticed by the user; the back-up heater will serve the demand. Taking this into account, the most critical item to be considered is "complexity and reliability".

Based on this, sound system solutions for solar powered hot water systems should be simple and solid system configurations, meaning: systems are composed with as few as possible (moving) parts and complex hydraulic solutions are avoided. This will also decrease installation costs and mistakes. The optimal/desirable configuration in this case is a system without electronic control unit(s), and pump(s) and a few additional valves.

Simple solution

System configurations with centralized collectors and solar storages and de-central back-up heating (configuration 3) seems to meet to a large extend the technical criteria. Especially if systems will be applied with integrated collector storage – ICS- (collector and solar storage in one component) which can operate without pump and pump control. Only special attention has to be paid to organise the maintenance (which is minimal) and invoicing of hot water use.



A collective solution with ICS systems is given in Fig. 3. The ICS units on the roof can be connected in parallel (Tichelman) to a collective supply of cold water. The warm water from the systems is distributed to the apartments. This system can be used up to about 6 apartments in strings. The number of systems does not have to be equal to the number of apartments.

Fig. 3: Simple collective solution with ICS systems for apartments.

Exploitation and invoicing

There are several options to distribute the costs of the water. The choice is up to the project developer and/or the customer:

- Only measure the total amount (WMB) and distribute the costs evenly over all apartments.
- Measure the amount of preheated water to every apartment (WM1B to WM3B).
- Install WMB as well as WM1B to WM3B and let the choice how to distribute the costs to the apartment owners.

Item	1 standard solar water heater	2 total centralized system	3 centralized solar system with de-central back-up	4.1 de-centralized solar system, parallel, central control	4.2 de-centralized solar system, parallel, de-central control	4.3 de-centralized solar system, series, central control
Suitability	Only applicable to the 2 to 3 top storeys in MF building. Additional space needed in dwelling for solar storage (1m²).	Sufficient space needed for large solar storage and back-up heater in community area. No additional space needed in dwelling for solar storage and back-up. Specially interested for replacement of existing central hot tap water installation. Normally separate systems for space heating and hot water back-up heating.	Sufficient space needed for large solar storage in community area. No additional space needed in dwelling for solar storage. In the case a combination boiler is used, only one device is needed for space heating and hot tap water back-up heating.	Additional space needed in dwelling for solar storage (1m²). In the case a combination boiler is used, only one device is needed for space heating and hot tap water back-up heating.	Additional space needed in dwelling for solar storage (1m²). Can only applied in strings, so normally several strings needed per building. In the case a combination boiler is used, only one device is needed for space heating and hot tap water back-up heating.	Additional space needed in dwelling for solar storage (1m²). Can only applied in strings, so normally several strings needed per building. In the case a combination boiler is used, only one device is needed for space heating and hot tap water back-up heating.
System performance	Standard, it is not possible to make use of simultaneousness advantages.	It is possible to make use of simultaneousness advantages, so less m² of collectors.	It is possible to make use of simultaneousness advantages, so less m² of collectors.	It is possible to make use of simultaneousness advantages, so less m² of collectors. Central control with de-central solar storages results normally in a non-optimal system performance.	It is possible to make use of simultaneousness advantages. Optimal system performance, due to de-central control. Each dwelling can use the whole collector array.	It is party possible to make use of simultaneousness advantages. Overall system performance the same of higher as de-central parallel (4.2). Due to higher collector circuit resistance, higher pump capacity needed.
Heat losses	Only collector circuit heat losses; depending on the number of storey. High heat losses of solar storages; 2 to 3 times higher than central storage.	High. If solar storage is placed in basement large collector piping needed. Recirculation circuit needed between back-up and taps. High losses (circulation 60° water 24 h/day). Also back-up efficiency has to be taken into account. Low heat losses of solar storage.	High. If solar storage is placed in basement large collector piping needed. If recirculation circuit is applied between solar storage and back-up heaters medium high losses but less than centralised system (2), lower average temperature.	High collector circuit heat losses. Normally a large quantity of piping per dwelling is needed for collector circuit. High heat losses of solar storages; 2 to 3 times higher than central storage.	Medium collector circuit heat losses. Less quantity of piping per dwelling compared to 4.1. High heat losses of solar storages: 2 to 3 times higher than central storage.	Low-medium collector circuit heat losses. Less quantity of piping per dwelling compared to 4.2. High heat losses of solar storages; 2 to 3 times higher than central storage.
Complexity & reliability	Standard, reliable systems. Each dwelling has his own complete system. If one control or pump fails, this will only affect the dwelling of the event.	Not complex system, limited amount of standard components needed. If control or pump fails, this will affect all the dwelling connected.	Not complex system, limited standard components needed. If control or pump fails, this will affect all the dwelling connected.	Complex system, especially the collector circuit. Various types of valves needed per dwelling. Difficult to adjust flows and control. Specialized solar installers required. If control or pump fails, this will affect all the dwelling connected.	Quite complex since each dwelling has his own control and pump. Additional valves needed. Less problems to adjust flows and control compared with 4.1. Specialized solar installers required. If one control or pump fails, this will only affect the dwelling of the event.	Not complex system, limited amount of standard components needed. If control or pump fails, this will affect all the dwelling.
Investment costs	As standard single family dwelling with additional piping costs depending on the storey.	Investments costs solar system low. Investment cost for recirculation circuit can be considerable.	Investments costs solar system low. Investment cost for recirculation circuit can be considerable. Investment costs for back-up higher as central back-up (2).	Investment costs high, mainly due to complex and large collector circuit, additional valves and a number of small solar storages. Costs for de-central solar storage up to 2 times higher than central storage.	Investment costs high, mainly due to separate control units pumps and a number of small solar storages. Costs for de-central solar storage up to 2 times higher than central storage.	Investment cost solar system lower than de-central parallel systems (4.1 & 4.2) mainly because of less components needed, but higher than 2 and 3 due to a number of small solar storages. Costs for de-central solar storage up to 2 times higher than central storage.
Exploitation & invoicing	Each dwelling has his own complete system. No separate invoicing is required.	Have to be taken care of by the association of tenants. Invoicing of hot tap water and back-up energy. Not possible for exact invoicing per dwelling if no additional water meters are installed (per dwelling).	Have to be taken care of by the association of tenants. Invoicing of hot tap water. Not possible for exact invoicing per dwelling if no additional water meters are installed (per dwelling).	No separate invoicing is required.	No separate invoicing is required.	No separate invoicing is required.
Maintenance	Normal, each tenant will take care of his own system	Have to be taken care of by the association of tenants for the solar system and back-up.	Have to be taken care of by the association of tenants for the solar system. Back-up heater by tenant.	Have to be taken care of by the association of tenants for the solar collector part. Solar storage and back-up heater by tenant.	Have to be taken care of by the association of tenants for the solar collector part. Solar storage and back-up heater by tenant.	Have to be taken care of by the association of tenants for the solar collector part. Solar storage and back-up heater by tenant.

Table 2: Analyses of different solar powered hot water system configuration for multi-family houses

Conclusion

- An initial estimation of the MFH market shows an annual potential of around 820 MW_{th} (ca. 1,2 million m^2) that can be developed in the coming years.
- Over 40% of this potential (350 MW_{th}) can be found in Spain followed by Germany and France with 150 MW_{th}. The annual potential in Spain exceeds the total accumulated installed capacity in 2004. The main market in Spain will be the newly build MFH due to the fact it is obliged by law as from the end of September 2006 onwards.

- For the application of solar powered hot water installation in MFH different system configurations can be applied which all have there pros and cons concerning technical and non-technical issues. In general the total market and actors are served best if solutions are applied that will deliver solar powered hot water over 20 years without technical problems and a minimum maintenance requirement.
- So, sound system solutions for solar powered hot water systems are simple and solid system configurations, meaning: systems are composed with as few as possible (moving) parts and complex hydraulic solutions are avoided. The optimal/desired solution is a system without electronic control unit(s), and pump(s) and a few additional valves. System configurations with centralized collectors and solar storages and de-central back-up heating seems to meet to a large extend the technical criteria. Especially if systems will be applied with integrated collector storage (collector and solar storage in one component) which can operate without control unit. Only special attention has to be paid to organise the maintenance (which is minimal) and invoicing of hot water use.

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System concepts for collective solar thermal systems across Europe

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Introduction

The EU funded project NEGST (New Generation of Solar Thermal Systems) aimed at the establishment of more cost-effective solar thermal systems with high performance on the European market. One core field of attention was dedicated to "Standardised concepts for large solar thermal systems".

Overall 18 European research institutions and associations from 13 countries form the project consortium of NEGST. In the work dedicated to collective solar thermals systems (CSTS), participants from Austria, Germany, Greece, the Netherlands, Norway, Sweden and Spain were involved. By establishing a coordinated investigation in the separate countries and summarising the results at a European scope, a wide overview of today's technology and the most relevant barriers and chances for the broader application of CSTS could be reached.

To illustrate the current dissemination of this kind of systems, Fig. 1 presents the status of installed solar thermal capacity within collective solar thermal systems (collector surface larger than 30 m²) by the end of 2005 in a number of European countries.

The data for the installed capacity of CSTS and the fraction it represents of the total nationally installed capacity are partly based on statistic references, partly on estimations of national associations or experts. According to the graph, the largest total amount of CSTS can be found in Austria, Switzerland and Spain. The highest market share they present in Norway, Sweden, Switzerland and Spain. In the currently largest European solar thermal markets Germany, Austria and Greece, the fraction of CSTS of the total installed capacity is comparatively low.

Standardised system concepts

The core issue of the presented work package dealing with large solar thermal systems was the survey and characterization of promising hydraulic layouts that exhibit a large potential for becoming standards in system design for the future. In combination with this, existing and potential standardised components for large solar thermal systems were investigated.

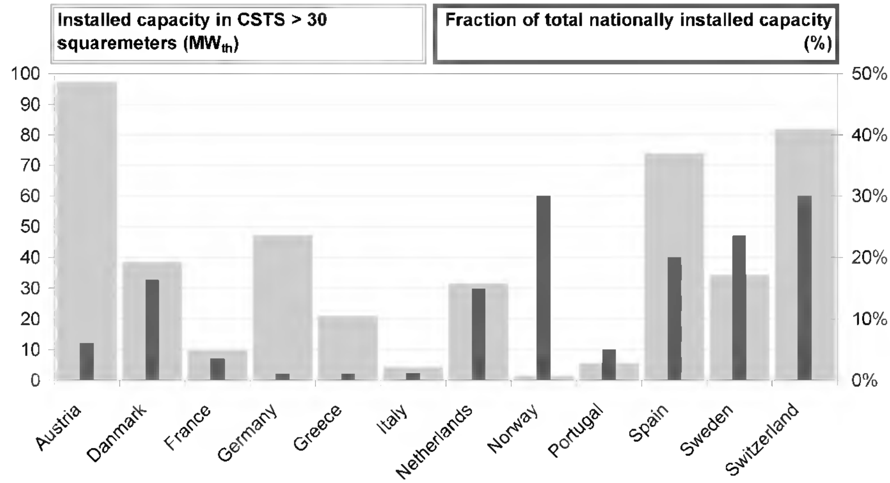

Fig. 1: Dissemination of solar thermal systems with a collector surface larger than 30 m² in various European countries (state by the end of 2005)

As a methodical approach, good practise systems in the participating countries were investigated and national experts have been consulted for their experience on good system design. As expected, the evaluated CSTS widely exhibited an individual hydraulic design. This is especially true for installations with long-term storage and such for solar cooling purposes. On the other hand for common applications such as domestic hot water heating or space heating in dwellings or in hotels, a certain level of standardisation for the design of CSTS could be observed mainly in Central European markets such as Austria, France and Germany. Some of the system concepts have even been investigated metrologically.

The least references for system standardisation could be found in Southern European and Scandinavian countries. In Sweden and Denmark according to the given infrastructure of heat supply, large solar thermal systems are frequently attached to district heating grids. For dwellings, no major approaches of standardisation for solar thermal systems could be observed. In Greece, CSTS are mainly used in tourism facilities where in most cases the necessity of an individual hydraulic layout is given. In multi family dwellings, to the larger part individual thermosyphon systems are used so that the application of collective systems is still rather low in this segment in Greece.

Different in Spain, where due to legislative measures a rapid growth of CSTS is reported in the last years. In many parts of Spain central heat metering is not a standard practice. For this reason, and different to the other analysed hydraulic layouts, central solar thermal systems are installed but auxiliary heating is done decentralized in each apartment (see Fig. 2).

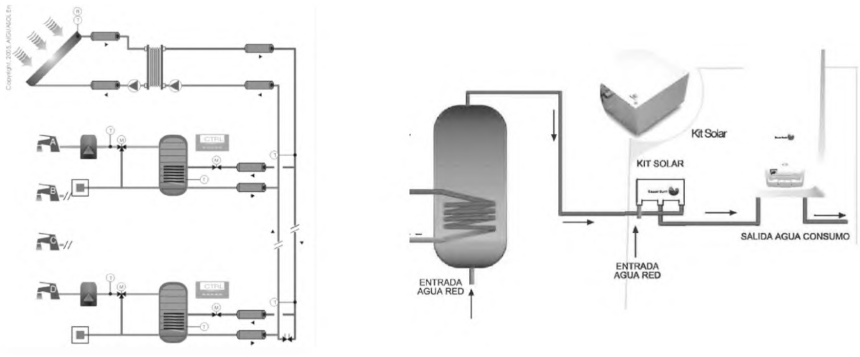

Fig. 2: Typical Spanish hydraulic layout with decentralized back-up heating (Sources: Aiguasol, Saunier Duval)

Unfortunately, the performance of this frequent system concept could not be verified as neither independent monitoring data nor guidelines for system dimensioning and design could be researched.

Also in the south of France the described Spanish concept with decentralized back-up heating is reported to become increasingly applied. During the past years and up to now though, solar preheating systems with central integration of the auxiliary heater have dominated the French market for CSTS. Most frequently, serially coupled solar storage tanks that are filled with domestic hot water are applied, so that a thermal separation of the solar and conventional part, including circulation line, can be realized by the integration into separate tanks. The application of this system concept was encouraged by the French funding scheme in combination with performance guarantees for many years and good proven results are available. Also in Scandinavia, systems with domestic hot water storage tanks gained good reputation in a survey amongst technical stakeholders performed in NEGST.

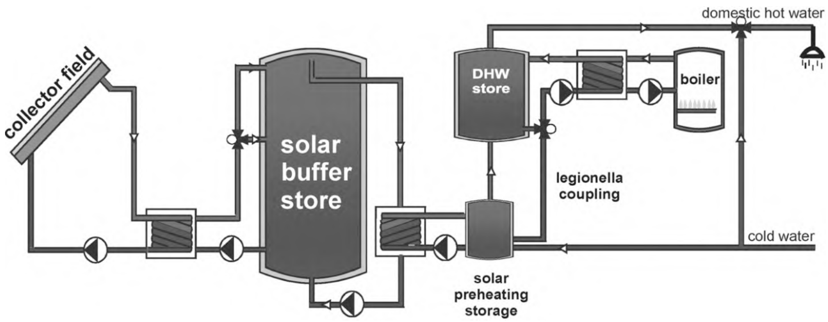

Fig. 3: Typical German domestic hot water preheating system (Source: ITW)

Like in most other European countries, in Germany, CSTS have up to now mainly been installed to support the preparation of domestic hot water. Hydraulic optimisation in terms of hot water hygiene and efficiency of the solar thermal system has led to a system layout as shown in Fig. 3.

The solar heat is stored in an energy storage tank and the domestic hot water is heated via external heat exchangers. Extensive measurement results and planning guidelines for this kind of system layout are available from the national research program *Solarthermie 2000.*

Similar solar thermal domestic hot water preheating systems, but with a primary solar circuit constructed with the drain-back principle, are reported to dominate the market for CSTS in the Netherlands with a market share of roughly 80%.

Going along with the development in the single-family house sector, in Central Europe, CSTS are increasingly integrated to also support the space heating demand of dwellings and hotels. In Austria, a standardised layout with energy store and auxiliary heat integration in combination with the decentralized preparation of domestic hot water has gained very good reputation amongst housing societies (see Fig. 4). The heat distribution is realized via a pair of pipes. Domestic hot water is prepared decentralized with pre-fabricated apartment heat transfer units that additionally guarantee low temperatures in the return line of the distribution grid. In new dwellings, systems of this kind are typically dimensioned to reach solar fractions of 10–20% of the total heat demand of the building.

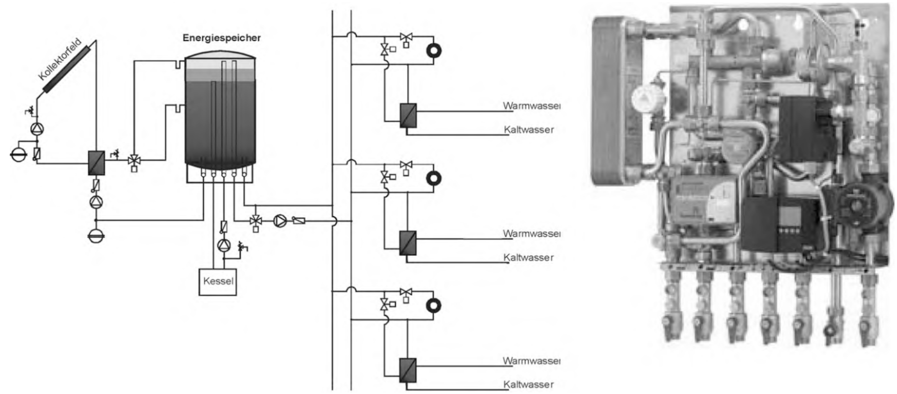

Fig. 4: Concept with decentralized domestic hot water preparation and pre-fabricated appartment heat transfer unit (Sources: AEE INTEC, Danfoss)

Apart from the pre-fabricated apartment heat transfer units, the concepts described so far rely widely on components not specifically designed for the application in solar thermal systems. Like in the single-family house sector, solar companies currently push forward the development of pre-assembled hydraulic groups especially designed for the use in solar thermal systems also for CSTS. Unfavourable and overcomplicated hydraulic layouts designed by inexperienced planners that were in the past frequently responsible for weak performances of individually planned larger solar thermal systems are substituted by proven concepts of specialized companies. These concepts guarantee the proper realization of the general basic principles of good solar thermal system design.

Especially in Germany and Austria, standardised hydraulic groups have been introduced to the market in the past years and show increasing success. An example is the system concept of the company Solvis shown in Fig. 5.

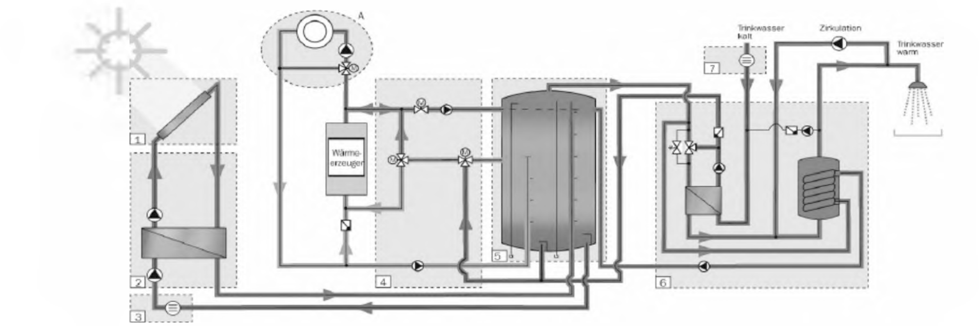

Fig. 5: Standardised combisystem with pre-assembled hydraulic groups marked grey (Source: Solvis)

From a central storage tank, pre-assembled hydraulic groups arrange the integration of the solar thermal system part, of the auxiliary heating and distribution lines, guaranteeing good operation conditions for all system parts with an integral controlling strategy. Parts of the domestic hot water preparation, space heating demand and the energy demand of the circulation line can be supported by the solar thermal system resulting in the possibility of high solar thermal fractions also for larger applications. Compared to the earlier described combisystem concept with a heat distribution via two pipes, which finds its application mainly in new dwellings, this system concept is especially suitable for retrofitting existing central heating systems that typically have four distribution lines in Central Europe.

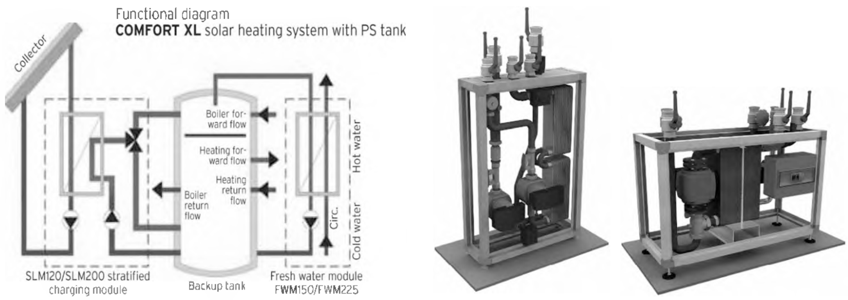

Fig. 6: Standardised combisystem with pre-fabricated hydraulic groups (Source: Sonnenkraft)

A further example for a standardised concept for large solar combisystems that has been successfully applied in tourism facilities and dwellings across Europe in recent years is shown in Fig. 6.

This system of the company Sonnenkraft is designed with a central storage tank and two pre-fabricated hydraulic blocks. Similar to the concept of Solvis, the preparation of domestic hot water is realized with a so-called 'fresh water unit' that supports domestic hot water consumptions of up to 150 litres (55°C) per minute. The integration of the solar heat, the circulation line, the space heating circuit and the auxiliary heating is arranged by the hydraulic modules according to the given temperatures at different levels of the central storage.

Conclusion

Within the research performed, a number of promising approaches for the standardisation of hydraulic layouts of CSTS could be identified. Even though the described approaches are sticking to a small number of principles to guarantee the efficient performance of the solar thermal system part, there is a big variability of solutions especially at the interface from the solar storage tank to the auxiliary heater and heat distribution. This is mainly because of the different traditional designs of heating systems in the individual countries. For the described approaches for standardisation there are partly extensive planning recommendations and handbooks available that ease the application of large solar thermals technology for planners and installers.

The increasing pre-fabrication of essential hydraulic component groups represents a promising development in terms of quality assurance in planning and installation. It can be expected, that this development will intensify in the coming years and an increasing number of solar companies enter the market with standardised solutions for CSTS.

The NEGST work package dedicated to collective solar thermal applications such as for multi-family houses or tourism facilities resulted in a number of resource documents on the technological but also organizational state of affairs in connection with CSTS in Europe. On one hand the reports serve HVAC professionals with an overview on rewarded hydraulic design, recent innovations in component standardisation and concepts for plant supervision.

On the other hand, consultants and policy makers profit from the documentation of experiences on quality assurance and market enlargement that have not been described in detail within this article. Collateral measures for making CSTS more attractive for investors were investigated to identify promising starting points for national incentives for the promotion of large solar thermal technology.

The provided reports include collections of contact persons and publications for the respective issues. The given information is meant to serve as a link to selected national and international expertise in the field of collective solar thermal applications.

Reference

The documents can be downloaded in English language from the project website http://www.swt-technologie.de/html/negst.html.

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Comparison of ICS with thermosyphon type solar water heaters

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Abstract

Integrated Collector Storage (ICS) type solar water heaters have dual operation, to collect solar radiation and to preserve the heat of the stored water. We present improved ICS systems consisted of truncated CPC symmetric reflectors combined with one horizontal cylindrical storage tank. The used CPC reflectors results to sufficient temperature rise of the stored water during daily operation of ICS systems and the use of black selective absorber or/and double transparent cover contributes to satisfactory preservation of the hot water inside the storage tank during the night. These ICS solar systems and also typical flat plate thermosiphonic units have been experimentally studied for 12 h and 24 h operation without water draining. The main objective of this paper is to draw detailed energy and environmental profiles for the investigated solar devices to determine the yearly obtained thermal energy regarding the mean water temperature during the daily operation of them. The environmental profile is assessed through the use of Life Cycle Assessment method (LCA), aiming at evaluating the different systems from the environmental point of view, by calculating the values for energy payback time. The results confirm that the ICS systems present satisfactory energy and better environmental performance compared to the corresponding performance of typical flat plate thermosiphonic units.

Introduction

The well known Flat Plate Thermosiphonic Units (FPTU) and the less widely applied Integrated Collector Storage (ICS) systems are small size solar water heaters, aiming at covering domestic needs of 100–200 l of hot water per day. ICS solar systems have simpler construction and lower cost than FPTU systems, as they consist of solar collector and water storage tank mounted together in the same device. The preservation of the stored water temperature at an acceptable level is the main problem of ICS systems, because a significant part of their absorbing surface area is exposed for the absorption of the solar radiation. This, results to smaller ability in preserving the water tank temperature during the night, setting limitations to their application.

Extensive studies on ICS solar systems with cylindrical water storage tanks placed properly inside stationary symmetric or asymmetric type of Compound Parabolic Concentrating (CPC) reflector troughs have been performed in the Physics Department at the University of Patras [1–4]. These systems can be used as separate units for one family houses and also in series connection for large size applications. In all energy applications, the impact of the used technology to the environment must be considered. The Life Cycle Assessment (LCA) method is suitable tool to get results concerning the energy pay back time, the CO_2 pay back time and other environmental factors. This methodology considers the embodied energy from conventional sources in several energy systems for all their life and also determines their impact to the environment. Among the studies on this subject and regarding the systems that are based on the use of the renewable energy sources, there are some works referred to solar energy systems [5–8]. The LCA method has been extensively used at the University of Rome "La Sapienza" [9], mainly on the study of photovoltaics and recently it has been applied to ICS systems [10].

In this paper we present experimental results during the daily operation (without water draining) of some investigated ICS solar water heaters, in comparison with corresponding results of typical flat plate thermosiphonic units. In addition, the yearly calculated thermal energies of all studied systems for specific operating temperatures are assessed through the LCA method. The calculated values are considered to the thermal performance and the environmental effect of the developed solar devices.

ICS and FPTU solar water heaters

ICS systems are considered alternative solar devices to FPTU systems (Fig. 1) and consist of one or more water storage tanks, where all or a part of their tank surface is exposed for the absorption of solar radiation. Metallic type cylindrical water storage tanks are used in most commercial ICS systems, as they resist to the pressure of the water mains. ICS systems with vertical (north–south orientation) storage tank mounted inside their CPC reflector trough, present effective water temperature stratification. The ICS systems with storage tank at horizontal (east–west orientation) mounting have efficient behavior in water heating during day and also in water temperature preservation during night [3]. Thermal protection of the storage tank is less effective in ICS systems compared to the fully protected tank of FPTU systems. Selective absorbing surface, double–glazing, transparent insulation and inverted or evacuated absorber reduce thermal losses by radiation and convection, are most of the suggested methods to preserve the stored water temperature. Among the investigated ICS models the most promising systems are those consisting of horizontal water storage tank mounted in symmetric CPC reflectors troughs, with selective absorber and one or two glazing cover [4]. These systems have practical size and moderate depth, considering the use of large diameter cylindrical storage tanks. In most of them a part of the cylindrical absorber can be thermally insulated to reduce thermal losses. In addition, they can be combined with involute or truncated CPC reflectors and therefore these ICS units have moderate aperture width. In this case the ratio of the storage tank volume per aperture area is increased, making the diameter of the cylindrical storage tank important factor considering the achieved water temperature rise.

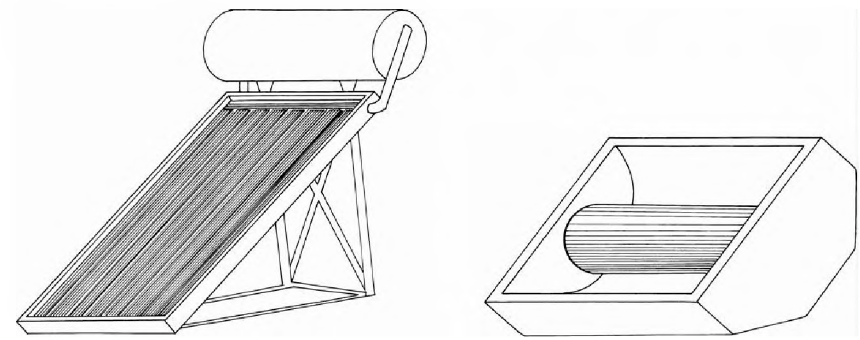

Fig. 1. FPTU and ICS solar water heaters.

ICS solar systems usually cover domestic needs of hot water of about 100–200 l per day. Considering that the aperture area of each ICS system unit can be up to about 2.0–2.5 m², the storage tanks diameter vary from 0.2 m to about 0.4 m. We have studied ICS systems with horizontal or vertical storage tank mounted inside curved reflector troughs and the test results have shown the effective use of non uniform distribution of the absorbed solar radiation [4]. Taking into account all the above, in this paper we study four types of the investigated ICS systems, two with one glazing cover and other two with double glazing and each system is studied with flat black and also with selective absorber. The experimental models consist of horizontal cylindrical water storage tank, properly mounted inside symmetric CPC reflector trough. The analytic equations of the reflector geometry and the design – construction details are included in recent published works [3, 4]. The studied ICS systems according to the used materials are: ICS 1A: mat black absorber and one glazing, ICS 1B: mat black absorber and double glazing, ICS 2A: selective black absorber and one glazing and ICS 2B: selective black absorber and double glazing. The four ICS models were tested without water drain and the recorded data were used to determine the temperature variation of the stored water, the mean daily efficiency of the systems and also their thermal losses coefficient during night. We did the same experiments for two FPTU solar systems, one with flat black absorber and a second one with selective absorber, while both have one glazing cover.

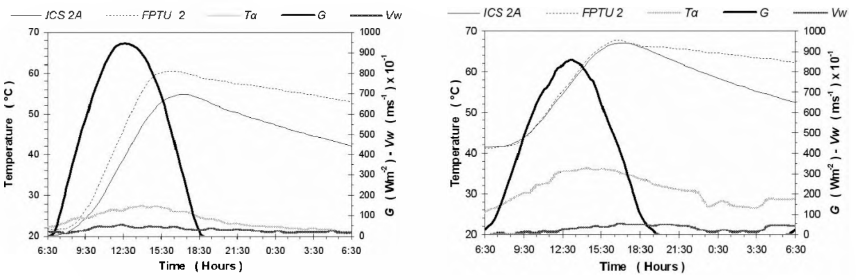

Fig. 2 Operation profiles for 24 hours no draw off testing of ICS-2A and FPTU 2

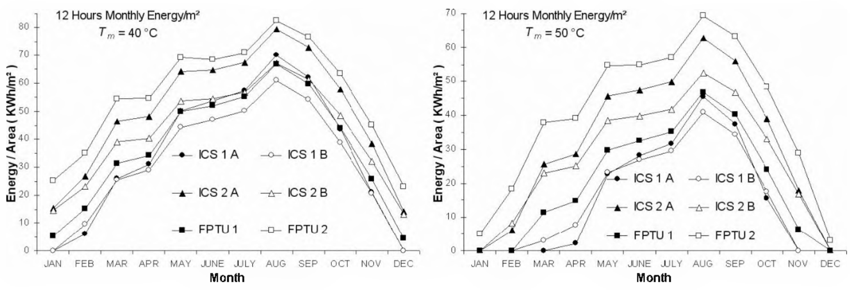

Fig. 3 Monthly calculated thermal energy of all systems for no draw off operation.

THE EXPERIMENTALLY ENERGY RESULTS

The above mentioned ICS and FPTU solar systems have been experimentally studied for no draw off operation [4]. In order to clarify the variation of the stored water during the 12 or 24 hours of no draw off operation, we give as example in Fig.2 the temperature profile diagram of systems ICS-2A and FPTU-2 for low (~20°C) and for medium (~40°C) initial temperature of the stored water. We calculated the monthly thermal energy of all systems for the weather conditions in Patras and we present in Fig. 3 the monthly energy variation diagram for mean stored water temperatures T_m=40°C and T_m=50°C. The yearly thermal energy is given per system (kWh) in Table 1 and per m² of system aperture (kWh/m²) in Table 2 (for the above two operating temperatures T_m). From the results of Tables 1–2 and from Fig. 2 and 3 we observe that ICS system has satisfactory thermal performance closed to that of FPTU, despite the less thermally protected water storage tank.

SYSTEM	*Yearly Energy per m²* (KWh/m²)	
	T_m = 40 °C	T_m = 50 °C
ICS 1A	421.43	182.94
ICS 1B	380.43	183.60
ICS 2A	595.58	378.85
ICS 2B	504.39	325.38
FPTU 1	444.37	241.67
FPTU 2	668.85	480.03

SYSTEM	*Yearly Energy* (KWh)	
	T_m = 40 °C	T_m = 50 °C
ICS 1A	341.36	148.18
ICS 1B	308.15	148.28
ICS 2A	482.42	306.86
ICS 2B	408.56	263.56
FPTU 1	1097.60	596.90
FPTU 2	1076.84	772.84

Table 1 Yearly calculated thermal energy per m² for all studied systems
Table 2 Yearly calculated thermal energy for all systems

The Life Cycle Assessment (LCA) study

The LCA methodology was applied following the international standards [11]. Thanks to this analysis, a thorough assessment of the environmental performance of solar thermal collectors could be done, taking into account not only their operation, but their whole life cycle "from the cradle to the grave". The system boundaries include all the life cycle phases, considering collector disposal by landfilling with no material or energy recovery at the end of their technical life. If we look at the contribution analysis for the whole life cycle of an ICS collector, for three macro-phases, namely collector production, distribution and end-of-life disposal, we see that distribution and disposal phases give a very small contribution to the total impacts, lower than 2%, except for the indicator related to Solid Waste Production where, obviously, the disposal step shows a relevant share. Since the collector production phase contributes with the highest impacts, it is useful to analyze it in details. From now on, for the sake of simplicity, we focus on two indicators taken from the above list, namely Greenhouse Effect and Primary Energy Consumption, given the relevance of both indicators at a global policy level and the centrality of the latter in the analysis of an energy system, such as the solar collector. However, the conclusions drawn from the analysis, carried out by means of these two indicators, are quite general, since the results are fairly similar for all the environmental indicators that could be used. For both indicators, the main contribution comes from the production of the tubes, while lower shares come from transportation phases and support structures. Also the collector, which contains all the collector components, could give a relevant contribution. No pump is needed for both the collectors, therefore no electrical consumption for water circulation was considered during collector operation.

During their operation, the solar systems produce "green" heat, thereby displacing conventional energy sources (oil, natural gas). Therefore, the obtained environmental benefits due to the avoided environmental impacts are associated to the system operation phase. The benefits quantification depends on two parameters: the amount of thermal energy produced by the system in a given period (e.g. one year) and the conventional source partially replaced by collector operation. In the study herein reported, therefore, an environmental cost – benefit analysis was performed as well. This step was carried out in order to calculate the time period needed for the benefits obtained in the use phase to balance the environmental impacts in the whole life cycle of the collector. Environmental Pay Back Times (PBT) were calculated both for CO2 emissions and for primary energy consumption. The benefits were assessed for two different scenarios, depending on the conventional heat source partially replaced by the solar collector: natural gas or electricity. The results showed that Energy Pay Back Time (EPBT) and CO2 PBT ranges from 5 to 19 months. Both the environmental PBTs are remarkably lower than the average life time of the collector (15÷20 years) and this means that the production and the operation of this kind of solar collectors make sense, from an environmental point of view, also in a life cycle perspective.

The study results underline that, from an environmental point of view, the most critical phase is the collector production step; besides, LCA outputs could be used for collector "Eco-design", choosing different materials and components, in order to improve its global environmental performance. Finally, it should be noticed that the environmental pay back time values are remarkably lower than the expected lifespan of the system, meaning that the solar plant very soon begin producing clean energy.

Conclusions

We studied four types of ICS systems that were investigated at the University of Patras, Greece. The thermal performance of these ICS systems was compared to this of two FPTU solar water heaters and the obtained thermal energy for the weather conditions in Patras during a hole year was calculated. The results showed that the new ICS systems are more efficient than the typical FPTU systems in the energy pay back times if we consider 12 hours of no draw off operation. For longer time than 12 hours of no draw off operation the thermal losses of ICS systems are higher and finally FPTU systems give better results. But considering that this is not a typical operation mode for these systems, as the hot water consumption is more or less from noon until late evening, the suggested ICS systems could be considered promising solar devices.

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ΕΛΛΑΔΑ 2008
Ανάπτυξη παντού. Ανάπτυξη για όλους.

ΥΠΟΥΡΓΕΙΟ ΕΘΝΙΚΗΣ ΠΑΙΔΕΙΑΣ ΚΑΙ ΘΡΗΣΚΕΥΜΑΤΩΝ
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ΠΑΙΔΕΙΑ ΜΠΡΟΣΤΑ
2ο Επιχειρησιακό Πρόγραμμα
Εκπαίδευσης και Αρχικής
Επαγγελματικής Κατάρτισης

Thermosiphon Systems: Market, State-of-the-Art and Trends

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Introduction

90 percent of solar domestic hot water systems installed worldwide are thermosiphon systems [1]. In the past, these systems have not been an object to research and development activities of most European manufacturers. This is also reflected by the small number of scientific publications on thermosiphon water heaters, which is the more surprising considering their enormous market potential. In standard solar-thermal literature, thermosiphon systems are mostly only mentioned in very few sentences.

Fig. 1: Markets for Thermosiphon Systems around the Mediterranean Sea

In spite of this lack of research, thermosiphon systems are currently becoming more and more interesting for European manufacturers of solar-thermal components and systems. These manufacturers are confronted with increasingly saturated local mar-kets, and therefore look for possibilities in ex-port, mainly concerning regions around the Mediterranean Sea (Fig. 1). In these regions, thermosiphon systems respond to the customers' demands in an ideal manner, be-cause the production of daily hot water is sufficient and there is no need for house heating. Thermosiphon systems replace the commonly used electrical water heaters.

1. Market analysis

1.1 Europe

It is the European Union's (EU) aim to increase the solar-thermal collector area currently installed in its member countries to 100 Mio. m², which means a total capacity of 70,000 MW_{th} [2] (converted from the solar-thermal collector area with a factor of 0.7 kWh_{th}/m^2).

Towards the end of 2005, the total capacity of all European solar thermal systems was about 11,175 MWh_{th}, which equals a collector area of about 15.96 Mio. m² or only about 16% of the target of the EU. These figures should not be overestimated as the market growth in Europe, according to preliminary figures of ESTIF, was about 35% in 2006 – an increase of the installed collector area of about 2.7 Mio. m².

Apart from Europe's three main solar thermal markets – Germany (47%), Austria (12%) and Greece (11%) – which together represented about 70% of the entire European market in 2005, markets like Spain, Italy or France are becoming more and more important.

If Spain and France are considered to be examples for the developments within Europe, good market possibilities can be attributed to providers of solar-thermal components from countries like Germany or Austria. Large parts of both countries, Spain and France, to a very big extent are also very interesting as far as the use of thermosiphon solar systems is concerned.

Especially France, without its overseas, had a market growth of about 134% in 2005. The reason for this development is the so called 'plan soleil' (sun plan). Since 2006, 50% of the acquisition cost within this programme can be rebated from the incoming tax. France, according to the words of its industrial minister, wants to be Europe's leading market for solar thermal applications by 2010.

Spain had a market growth of only 19% and stayed below the European average in 2005. But in September 2006, a law came into force which makes it necessary for almost all newly built houses to produce 30...70% of needed hot water by solar energy. With this legal obligation, Spain serves as a pioneer within Europe. This law will also lead to a noticeable market growth within the next years [3].

1.2 North Africa and Middle East

Moving *away* from the European solar-thermal market and focusing on the North African market, only little financial possibilities can be found on the inhabitants' side. But especially these economically weak countries are ideal for the use of solar-thermal applications.

In Tunisia for example, the estimated Gross Domestic Product (GDP) was only about 2,240 US-$ in 2006 (for Germany 25,270 US-$ were predicted) [4], but Tunisia has an annual amount of sunshine hours of about 2800 ... 3200 h/a at an ambient temperature of about 20 °C.

These prevailing conditions make all Northern African countries like Tunisia, Algeria, Libya, Morocco and Egypt ideal markets for the most simple solar-thermal water heaters of all – the thermosiphon systems.

To return to the example of Tunesia, various efforts have been made by the German-Tunisian chamber of commerce and industry, which has noticed the demand for a presentation of German solar-thermal and photovoltaic techniques in order to create joint ventures and enable German manufacturers to reach new markets [5].

In the Middle East, especially Israel attracts attention due to its high density of thermosiphon solar water heaters. One reason for this has been the legal restraint, introduced in 1980, to install solar-thermal water heaters when building a new house. Meanwhile solar-thermal applications are accepted and are seen as cost-efficient investment among the inhabitants, which is reflected by the figures. Four times more solar-thermal systems are voluntarily renewed than are included into new buildings [6].

2. State-of-the-Art

In a worldwide market-analysis, the data of more than 50 thermosiphon system manufacturers were collected and evaluated. As a result of this analysis, the following trends on the main specifications of the system can be observed.

2.1 Collectors

Thermosiphon systems, outside of China, commonly use flat-plate collectors. Only a few manufacturers include, in most cases, non-pressurized systems with evacuated tube collectors in their programme (Fig. 2).

In contrast to the rest of the world, solely thermosiphon systems with evacuated tubes are sold in China. There are two main reasons for this:

- Evacuated tubes are produced very cheaply within China. But these tubes barely reach the quality and durability of those produced in Europe. Therefore the export share of Chinese solar thermal applications is still low.
- In China, most of the thermosiphon systems sold are totally non pressurised systems, with only one hydraulic circuit. In these systems, collector and storage build one unit together, as the evacuated tubes are plugged in the storage tank especially perforated for this sake, which is very cheap to produce.

Regarding only flat-plate collector thermosiphon systems, many manufacturers have several different absorber coatings, according to the climatic and customers' demand in their programme. In most cases, the same system is available with a solar black painted absorber or a selective coated absorber.

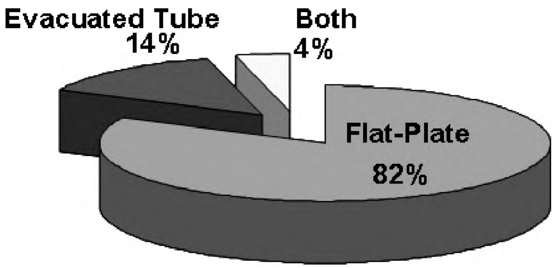

Fig. 2: Used Collectors for Thermosiphon Systems

2.2 Storage Tank

Regardless of the collector type used, horizontally installed storage tanks are dominating, vertically oriented storages being an exception (Fig. 3). The aesthetic advantage of horizontal storages is that these systems can be built optically compact. Another advantage of lying systems is that they can be installed easier on a system mounting or an inclined roof.

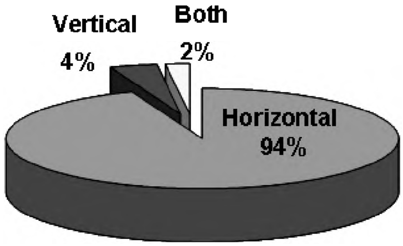

Fig. 3: Storage Tank Position

An essential advantage of a standing storage tank is the achievement of good temperature stratification.

2.3 System Pressure

Surveys clearly show the customers' demand for systems that operate under tap pressure. In most cases, non-pressurised systems come along with direct flow evacuated tube collectors.

2.4 Number of Hydraulic Circuits

A differentiation into one or two circuit systems reveals a trend towards systems with two hydraulic circuits. These systems are the most expensive ones to build, but, due to their collector circuit filled with antifreeze, offer one major advantage – they can be used in areas with frost, too. The maintenance of two circuit systems does also have an advantage, as possible contaminations, like lime and particulate material, in tap water can only be found in the storage tank – and not in the collector – where they can be removed, e.g. during a regular change of the sacrificial anode. In one circuit systems, these contaminations can be found in the collector circuit, also, where they narrow the pipe cross-section and reduce the system performance.

2.5 Typical System Sizes

There are two main sizes as far as thermosiphon systems are concerned. On the one hand there are systems with about 2 m² of collector area and approximately 150 l of hot water storage for households consisting of two persons. On the other hand there are thermosiphon systems available with about 300 l of storage volume and a collector area of about 4 m², which meet the requirements of households with about 5 persons. To ensure constant hot water quality, it is possible to offer a – in most cases electrical – backup heating for periods with adverse weather.

2.6 Comparison of Different Thermosiphon Systems

Looking at prices, adapted from available pricelists for thermosiphon systems on the world market, systems e.g. produced by market leader *Solahart* are found in the upper price segment (above 10 €/$l_{Storage}$).

Prices for systems by most European manufacturers seem to have been made in adaption to *Solahart*. In opposition to that, Chinese thermosiphon systems are sold at about 1/8 of the western prices (Table 1). There are several reasons for this:

- Chinese manufacturers use low-cost evacuated tube collectors and only simple steel storages.
- Chinese thermosiphon systems usually have no backup heating, so during winter and periods of adverse weather Chinese people can only use cold water.
- In China there is no government aid for solar-thermal components, that is why only cheap systems are affordable for people.

Because of what was just mentioned, it is only possible to sell simple, low-cost systems which work with non-pressurised water exclusively, and which have no antifreeze in the collector loop.

3. Trends

On the global thermosiphon market, two contradictory trends are observed from the German or Austrian point of view (Fig. 4).

On the one hand, it is necessary to reduce costs, because e.g. German manufacturers have to leave their local, technically well-engineered and expensive markets and are now confronted with competitors from Australia, Greece, Israel, Spain and Turkey.

On the other hand, the target markets are affected by a permanently growing living standard, hence an increasing demand for comfort which will result in higher demands on system performance and storage. Additionally, design and aesthetics are equally becoming more and more important.

Manufacturer: Type	*Solahart* (AU), 181 K_f	*Schüco* (D), TS150-1W	*Jiangsu Sunrain Solar Water Heater* (CN), TZ
			
Market price	11,10 €/ $l_{\text{storage volume}}$	10,70 €/ $l_{\text{storage volume}}$	1,70 €/ $l_{\text{storage volume}}$
Collector	Flat plate collector (system-dependent)	Flat plate collector (taken from standard programme)	Evacuated tubes
Absorber	Sandwich absorber (steel)	Cu tube register	
Coating	Black chrome	Sunselect	High selective
Hydraulic Circles	2	2	1
max. system pressure	10 bar	6 bar	Non pressurised
Storage tank	Double jacket storage	Double jacket storage	Steel storage

Table 1: Comparison of different thermosiphon systems

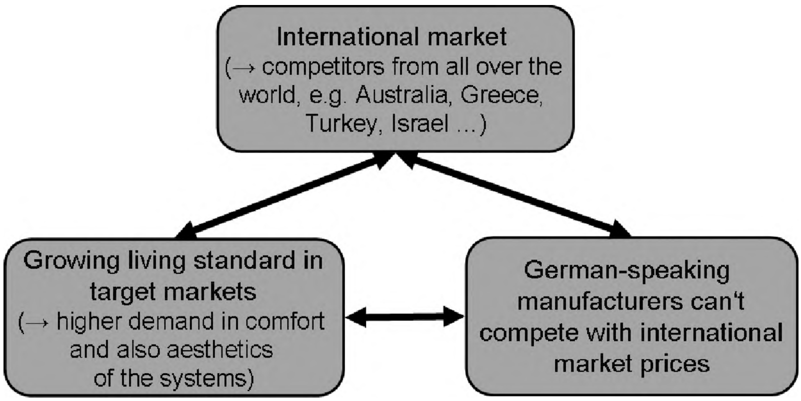

Fig. 4: Contradictory trends on the thermosiphon market

Conclusions

Markets for solar-thermal applications are currently experiencing a major growth worldwide. Poorer areas with a high amount of sunshine hours, in times of rapidly growing energy prices, discover the cost-free power of the sun for their daily hot water demand.

Especially for these regions, solar-thermal applications have to be developed, taking the financial possibilities and the ambient conditions into account.

The *Kompetenzzentrum Solartechnik* of *Ingolstadt University of Applied Sciences* (Centre of Excellence for Solar Engineering) has recognized the demand of applications for southern regions and will start to redevelop a thermosiphon system together with an industrial partner. The redevelopment is based on scientific principles in order to create a system without known problems like overheating and reverse thermosiphoning during night.

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Case study on a large scale drainback system in Ireland at the Bewleys Hotels, Dublin Airport

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Fig. 1: Bewleys Hotel, Dublin Airport

Introduction

Large scale solar thermal systems are still a rare sight, so it's good to see that readiness to invest is also apparent from abroad – in this case Ireland. The Bewleys Hotel Dublin Airport has sported a solar system in excess of 300 m² since the start of 2006. With 450 beds, the Bewleys Hotel is currently the largest hotel in Ireland.

Drainback technology

Systems which are known in Germany are mainly carried out using the technology usual in the market, involving a central system with permanently filled collectors. Conergy is also using proven technology in Ireland, namely drainback technology. The particular advantages of the drainback system are the omission of antifreeze measures as well as integrated overheating protection. The system also operates largely autonomously, requiring a minimum of operative support.

Reference system in Ireland

The solar-thermal system at Bewleys Hotel Dublin Airport was designed purely to heat drinking water, with the solar system also providing preheating. Thanks to the collectors, covering an area of 308 m^2, and a storage capacity of 2 x 5,000 litres, the system meets 30–40% of the warm water requirements of the Bewleys Hotel Dublin Airport. Three 5,000 litre storage tanks, indirectly heated by gas, provide support for the system.

Technical unique features of the installation

A technically unique feature is that this drainback system makes use of a difference in height of 30 m between the drainback storage tank and collectors, as the two components are seven floors apart. Overcoming such a difference in height poses a particularly technical challenge for drainback technology. The Bewleys Hotel system is the only drainback system in Europe that works with such a difference in height. In addition, collectors installed at such a height have to be able to withstand extreme wind speeds. Conergy designed all 55 collectors of the Conergy 56 P series for use in strong wind conditions. The heat transfer content amounts to 0.5 litres per square metre. The recommended volume flow is 0.015 $l/s/m^2$ (litres per second and square metre of collector).

Fig. 2: Collector field at the Bewleys Hotel roof and drainback tanks at the Bewleys Hotel

The 55 big collectors with serpentine flow were connected in two parallel fields. The feed and return of both collector fields into the building are joined in one side of the collector fields (no Tichelmann principle). The complete empty is ensured thanks to the smaller dimensioned feed. At the same time ensures the accruing under pressure the drainback effect – also known as super drainback. The full charging in return ensures also the same flow through of all collectors.

Fig. 3: Solar Feed and solar return

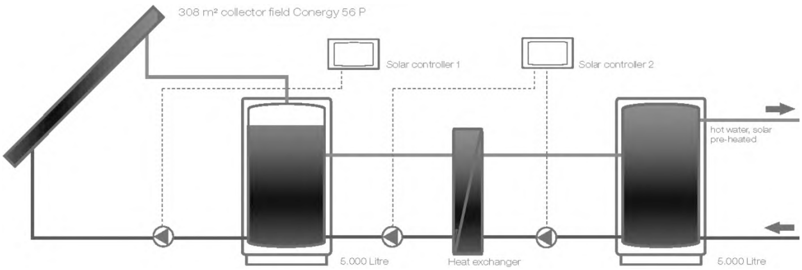

Fig. 4: Hydraulic Scheme of the drain back installation

Conclusions & outlook

The example of the Bewleys Hotel at the Airport in Dublin is demonstrating that the drainback technology for large scale systems is a high-level solution in terms of security and maintenance. Also from the economical point of view an investment in solar thermal systems on commercial buildings is getting more and more interesting. With the system on the Bewleys Hotel a Return on Investment of 10 percent was achieved.

The CTE from the point of view of the industry

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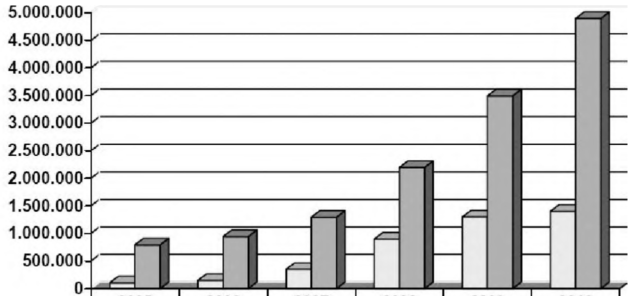
Introduction

Approved on March 2006, and obligatory since 29th September 2006, the new regulation created by the Spanish Government (Edification Technical Code, CTE in Spanish) to rule the aspects related to the edification activities, has established a hit in the development of the policies to promote the use of Renewable Energies. It requires that all new and refurbished buildings produce 30% to 70% of their hot water with solar energy. This is the first time that a national Government makes mandatory the use of solar energy.

But the CTE has to be seen as an instrument rather than a goal in order to achieve the full penetration of solar energy in the life of the Spaniards. It is the main tool to reach the objective of the national Renewable Energy Plan (PER): 4.9 millions of square meters in 2010 (795,500 m² in 2005).

These two facts have to be considered as the best opportunity that solar thermal energy has ever had in Spain. It is expected that the Spanish market will grow from 150,000 m² in 2006 to 1.4 millions in 2010 (Fig. 1), which represents an average of 1 million square meters yearly installed.



	2005	2006	2007	2008	2009	2010
M2 Instalados	108.000	150.000	350.000	900.000	1.300.000	1404500
M2 Acumulados	795500	945.500	1.295.500	2.195.500	3.495.500	4.900.000

M2 Instalados M2 Acumulados

Fig. 1: Market development forecast according to the PER (Source: IDAE 2005/ASIT 2006-2010)

The CTE and the PER are a challenge to all the players involved in this sector: building promoters, architects, engineers, manufacturers and installers. They all will have to make their best to score the set goal. If we also consider that 400,000 new houses are built per year in Spain, there are good chances to meet the objective.

Evaluation of the period passed since its application

Taking into account that a delay of approximately 1,5 to 2 years is usual, between the technical approval and the start of the a building works, it is rather soon to make a real evaluation of the new law, in terms of an increase of the demand. Until the beginning of 2008 it is not expected that the CTE has an impact on the market, a delay which causes some worry in the sector.

An analysis of how the expectative of the CTE is changing the solar thermal sector in Spain could, however, be done:

- The number of national manufacturers and installers is rising. Consequently, the manufacturing capability and collector availability are increasing.
- Public awareness of solar thermal energy has grown.
- The variety of products is becoming larger.
- Educational programmes and activities are exploding all across the country.
- New R & D projects are being set up.

In principle, all these items can be considered as good news. Unfortunately it is not possible at the moment to quantify them and make a more precise study, because there is no available data.

From the point of view of the industry

Regarding the other players in the sector, the requirements that they are claiming to the manufacturers are:

- Building promoters are willing to buy a large number of collectors at a price as low as possible.
- Architects are looking for integration-suitable products and maximum efficiency, if possible.
- Installers will prefer to get easy-to-use and quality collectors.

– Finally, it has to be guaranteed to the final customers the turnover of their investments. Quality trust products, efficient maintenance and a confident post-sale service are required.

In addition, it must be noticed that the relation of the final customer with the collector could change importantly: in the past, the final user of the equipment was its direct buyer. In the future, it is probable that user will not even see the collector. So the main characteristic that he will desire will be the reliability. Aesthetical matters that are not related with the architecture would pass to a second plane.

It has to be remarked that there is an important contradiction in these points: reliable and quality products are not the lowest-cost products that the building promoters want to install. They have to realize that acquiring a low-cost product is not an affordable long-period strategy. It has to be avoided that solar thermal energy would be considered as an untrustworthy subject.

An answer is given to the promoters' requirements: collectors' availability is going to be guaranteed by the manufacturers. And it is expected that economy-scale factors and well developed competition will reduce the prices.

Integration capability is one of the most desirable characteristics in a collector. A large effort has already been done along this line. In a short period of time, solar thermal systems will be fully incorporated into the buildings. Maybe this aspect is the most favoured by the inclusion of the solar thermal installations in the CTE.

Considering installation and maintenance services, there is an important difference between Spain and other countries like Germany or Austria. There is a lack of expertise and well prepared professionals.

Problems and improvements

The CTE is a law of minimum requirements: for example, it is necessary to define aspects concerning what kind of installation has to be done: centralized or decentralized. It is not regulating important future applications, as cooling and heating. It is expected that this will be achieved by 2010.

Although recently it has been approved a new regulation to certificate buildings energetically, the way to implement this regulation and how to organize it (audit entities, responsible, etc) are still pending. Solar installations have to be inspected and certified in order to guarantee the quality.

It is necessary to establish a national programme in order to instruct the future installers, which grants a professional certificate mandatory to set up a system. In addition, the Spanish organization ASIT is preparing a *best use guidance* to explain how to make an installation properly, to answer any doubt that could arise and to avoid any lack of information.

We have to diminish the great variety of installations' software that already exists, in order to standardize this matter. Some kind of regulation at this point would be desirable.

Finally, it has to be considered that manufacturers are increasing their activities to research and develop new solutions about materials and designs in order to improve the efficiency and reduce costs. They cannot make this effort without help; public funds designated to the solar thermal energy have to be amplified.

CONCLUSIONS

The introduction of the CTE regulations is going to be positive to the development of the solar thermal industry in Spain and it will make achievable the objectives described in the PER.

The impact on the market will not be noticeable until 2008. Although it has established an obligation, this has not been seen negatively by any significant part of the sector or the society. It has also served to change the way people look at renewable energies.

The Spanish government still has to improve the law in order to ameliorate some aspects, such as the organisation of building certificates and inspections. The lack of expertise of national installers has to be solved with new educational programmes.

Finally, public funds for research and development have to be enlarged, so that manufacturers can reduce further the production costs and increase the product performance.

The implementation of comprehensive quality assurance procedures in the manufacture of evacuated tube solar collectors

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ABSTRACT

Customer expectations within solar thermal markets continue to rise in relation to the supplied quality of solar thermal collectors, components and associated services. In an increasingly competitive market it is incumbent upon the manufacturers, suppliers and installers of solar collectors to meet these expectations by providing customers with the highest quality products and services. In this paper we report upon a comprehensive approach to quality assurance that has been adopted within an evacuated solar tube collector manufacturing facility over a 3-year period. In particular we will report upon the procedures adopted to assure quality in key areas of the supply chain and the manufacturing environment. In addition, we will also comment on the mechanisms adopted whereby customer feedback has been effectively utilised to focus attention on key areas in order to provide products and services that continue to exceed customer expectations and to drive defect rates to low ppm levels.

INTRODUCTION

The demand for solar thermal collectors and associated components has increased considerably over recent years with double-digit percentage growth figures being reported from markets throughout the European Union for 2006 [1]. This impressive growth is being reported from both traditionally strong and mature markets, such as Germany (+50%), Austria (+35%) and Greece (+10%), and also from emerging solar markets such as France (+75%) and the UK (+60%). Within most European Union markets growth in solar thermal is predicted to continue at double-digit percentage levels throughout 2007. As the market continues to grow this will place a heavy burden upon manufacturers to meet the higher demand on volumes and coupled with an increasingly sophisticated customer base Solar Thermal products with enhanced functionality and manufactured to the highest standards in quality and performance are requisite.

Defining A Strategic Plan for Continuous Quality Improvement

In order to address the increasing demands on quality, performance and functionality within the Solar Thermal Evacuated Tube market Thermomax embarked on a comprehensive drive to assure quality, performance and improve functionality across all products within the range. A strategic review to address these issues was undertaken in 2003 and as a result of this review process a 3-year strategic plan was put in place in order to position the company as the leading supplier of high performance, high quality solar thermal collectors. The basics of the strategic plan implemented covered three key areas identified in general as Management System, Product Design and Manufacturing.

The first key area of the plan was addressed with the full implementation of the ISO9001:2000 management system. The requirements of this standard were rigorously applied across all functions and operations within the organisation and compliance with the requirements of the standard were continuously evaluated through a comprehensive internal auditing schedule and random internal inspections.

The second key area was in the re-design the entire product range to meet increasing customer demands for improved products. A comprehensive review of the entire product range was undertaken and areas for product improvement identified. A number of design improvements were introduced across the product range and these have significantly contributed to the overall improvement in performance, quality, functionality and manufacturability of the entire range of products.

The third key area of our strategic improvement plan (which is the main focus of this report) was to develop robust processes and procedures relating to the supply chain, the manufacturing environment and customer feedback. The schematic shown in Fig. 1 highlights the main reporting and feedback mechanisms that were established across the manufacturing cycle to ensure the quality of materials and product from the supplier to the customer. Within this cycle the Quality Assurance function plays a key role in acquiring, analysing and disseminating details of non-conformances and ensuring the implementation of all corrective actions arising. This paper will highlight some of the key processes and procedures that have been adopted by Thermomax in order to implement a robust system to drive continuous quality improvement within the modern solar thermal manufacturing environment.

Quality Assurance in the Manufacturing Environment

Whilst there are many areas within the manufacturing environment that require attention in order to ensure that the highest levels of quality are maintained we will concentrate on a few key areas in this paper. The areas within the manufacturing environment that were identified for special attention were; Suppliers (SQA), Factory and Customers as shown in the schematic of Fig. 2. In each of these areas a review of the operational and reporting functions was undertaken and the actions required to improve the performance within each of the functional areas clearly identified and a plan of action put in place.

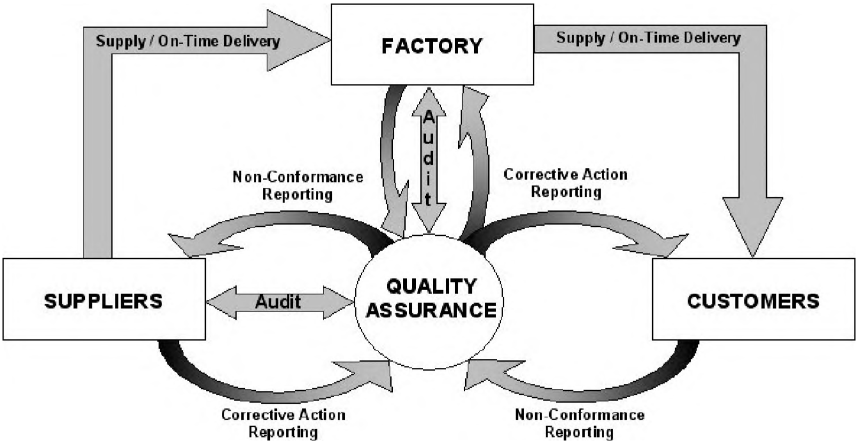

Fig. 1: Schematic detailing the key reporting lines within the manufacturing cycle and the critical function of Quality Assurance at the centre of this cycle.

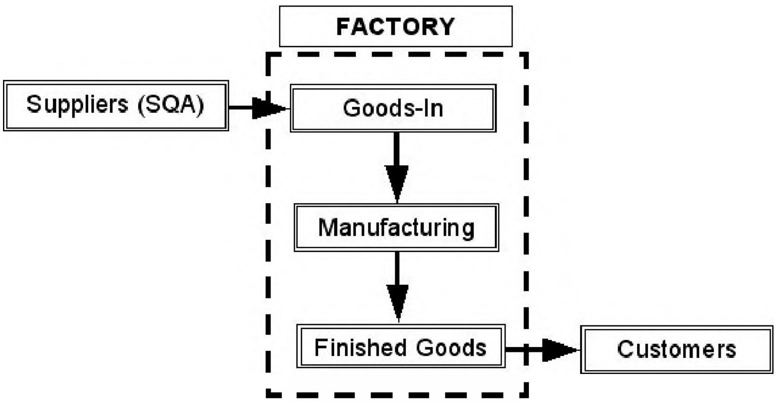

Fig. 2: Schematic detailing the key quality related areas within the manufacturing environment that were highlighted as areas for attention and improvement.

Supplier Quality Assurance (SQA)

A key area within our strategic development plan was to establish a high quality supplier base. In order to achieve this goal a range of comprehensive Supplier Quality Assurance (SQA) procedures were put in place. The SQA process adopted was based upon similar systems already in place within the automotive industry and consisted of three main areas as follows; Supplier Appraisal, Supplier Approval and Supplier Monitoring.

In the first instance all suppliers were subjected to a paper-based appraisal process that assessed and scored each supplier against specific areas in business, management and environmental systems. Each supplier was then subjected to a formal approval process that consisted of a full on-site audit covering all aspects of the management system and a detailed audit of the manufacturing environment.

In order to assure the ongoing compliance of the supplier base to acceptable quality standards a mechanism to continuously monitor supplier performance against a number of key performance indicators (KPI's) was implemented. In addition a formal process of non-conformance reporting to the supplier and corrective action reporting from the supplier was also put in place.

Factory: Goods-In

In order to assure the quality of product being introduced into the production line it was necessary to put in place a rigorous goods-in inspection regime. All incoming product was subjected to recognised receiving inspection levels as detailed in Table 1 [2]. The level of inspection for all incoming product is determined based upon two factors, i.e. the criticality of the part and the ongoing supplier quality rating.

THERMOMAX QUALITY SYSTEM

Batch Inspection Chart

Batch size	Sample size	Accept	Reject
Reduced Inspection			
2 → 8	2	0	1
9 → 15	2	0	1
16 → 25	2	0	1
26 → 50	2	0	1
51 → 90	2	0	1
91 → 150	3	0	1
151 → 280	5	0	1
281 → 500	8	0	1
501 → 1 200	13	0	1
1 201 → 3 200	20	0	1
3201 → 10 000	32	0	1
10 000 → 35 000	50	0	1
35 001 → 150 000	80	0	1
150 001 → 500 000	125	0	1
500 000 +	200	1	2

Batch size	Sample size	Accept	Reject
Normal Inspection			
2 → 8	2	0	1
9 → 15	2	0	1
16 → 25	3	0	1
26 → 50	5	0	1
51 → 90	5	0	1
91 → 150	8	0	1
151 → 280	13	0	1
281 → 500	20	0	1
501 → 1 200	32	0	1
1 201 → 3 200	50	0	1
3201 → 10 000	80	0	1
10 000 → 35 000	125	1	2
35 001 → 150 000	200	1	2
150 001 → 500 000	315	2	3
500 000 +	500	3	4

Batch size	Sample size	Accept	Reject
Tightened Inspection			
2 → 8	2	0	1
9 → 15	2	0	1
16 → 25	3	0	1
26 → 50	5	0	1
51 → 90	5	0	1
91 → 150	8	0	1
151 → 280	13	0	1
281 → 500	20	0	1
501 → 1 200	32	0	1
1 201 → 3 200	50	0	1
3201 → 10 000	80	0	1
10 000 → 35 000	125	0	1
35 001 → 150 000	200	0	1
150 001 → 500 000	315	0	1
500 000 +	500	0	1

Table 1: Table showing the standard batch inspection criteria for all products entering the factory.

All product that passes the goods-in inspection procedures are provided with a unique number and clearly identified as accepted material. Any product failing incoming inspection is immediately quarantined, labelled accordingly, reported via the non-conformance process and returned to the supplier for credit or replacement.

Factory: Manufacturing

An important aspect of the overall strategic quality improvement plan was to develop and foster an appreciation within the entire workforce in general, and throughout the manufacturing environment in particular, for the primacy of quality in all aspects of production operations. In order to develop an environment of continuous quality improvement across all the manufacturing operations it was identified at an early stage that responsibility for assuring the quality of product manufactured in all processes must lie with the operator(s) responsible for the production processes. Therefore the critical decision was taken at an early stage to remove all Quality Inspectors from the manufacturing environment. Responsibility for inspecting, approving and assuring the quality of all manufactured parts became the responsibility of the operator who manufactured each part, component or assembly. In addition a policy of "zero defects" was adopted throughout the production process and all operators were given responsibility, in line with certain control parameters, for identifying and removing (as scrap) any product identified with minor or major defects from any stage of the production line.

In order to implement this policy each process was provided with clearly identified acceptable quality standards and the operators provided with the necessary quality control equipment to check the critical dimensions of all manufactured parts. In critical areas of the production line where it was necessary to implement 100% inspection of manufactured parts camera inspection equipment was provided to enable all manufactured components to be accurately dimensionally checked against exacting standards.

In areas where critical components were manufactured and camera inspection equipment was not applicable nor suitable the process was subjected to Statistical Process Control with random samples regularly removed for measurement and analysis. Statistical deviations beyond the upper or lower control limits were immediately highlighted to production management and corrective actions immediately put in place to ensure the ongoing quality of the manufactured parts. In other areas of manufacturing where it was either not possible or practical to measure a component then the operators would be provided with bespoke gauges to monitor key critical parts.

An essential component to adopting such rigorous quality control procedures throughout the factory was to ensure the ongoing accuracy and compliance of all quality control checks, gauges and measuring equipment to international standards. A full software system to register and monitor gauges was put in place and all gauges were subjected regular inspection and calibrated to traceable national standards. In addition all processes were regularly subjected to random auditing to check compliance with work instructions and ensure correct gauge calibrations.

Factory: Finished Goods

A critical element in the overall drive for quality improvement within the manufacturing environment was the requirement to continuously monitor the quality of the finished product. A robust regime of finished product auditing was put in place with frequent and random audits undertaken by the QA department in order to assure the ongoing quality of the finished product.

The purpose of this audit regime was to determine the quality of the finished product and to assure that only product of the highest quality was being shipped to customers. Any defects identified during these audits fell into one of two categories, i.e. minor or major defects. Strict guidelines upon the actions/sanctions to be implemented in the event of defect identification were adopted as part of the audit regime.

In addition, the results of out-of-box audits are widely reported throughout the factory so that all production areas are fully aware of the quality standards being achieved in all process areas. The results from audits are regularly reported to operational meetings and regular review meetings and the necessary corrective actions put in place to remove all potential sources of defects within the manufacturing environment.

Customers

A key driver in the overall improvement of product quality was via customer feedback. In essence, customer feedback in the form of complaints or warranty claims were used in a constructive manner to drive quality improvements throughout the entire company in general and within the manufacturing environment in particular.

A database for logging all customer complaints/warranty claims was established and customer details and information would be logged accordingly. All complaints/warranty claims were carefully analysed and defective product subjected to detailed inspection to determine the root cause of any defect. In all cases where a valid complaint or warranty claim was established an immediate corrective action would be raised within the manufacturing environment to ensure that the defect would not recur. A full report upon the analysis undertaken and the corrective actions put in place would also be issued to the customer and the effectiveness of the corrective actions monitored on an ongoing basis.

Conclusions

As a result of the procedures adopted during the 3-year period detailed in this paper Thermomax has seen a significant improvement in product performance and quality, combined with an exceptional reduction of warranty related claims to low ppm (parts per million) levels across all Thermomax product ranges.

The significant improvement that has been achieved in quality across the entire product range can be attributed to general improvements in the following critical areas; Product Design, Prototype/Product Testing, Supplier Approval, Goods-In Inspections, In-Line Quality Control, Finished Goods Auditing and Customer Feedback. The approach that Thermomax adopted to quality improvement within the manufacturing environment has been precisely tailored to the requirements of the company and has been closely focussed on all of these critical areas with the results that defect levels on all new product ranges are in the low ppm levels and even into single digit ppm defect levels on a number of key products.

Although such low defect rates are an exceptional achievement within the Solar Thermal Industry Thermomax are continuing to put in place the necessary processes and procedures in order to competitively position the company to meet the demands of the rapidly growing Solar Thermal market throughout the next 3-year period so that the company is ready to effectively meet the challenges of the market in 2010 and beyond.

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Monitoring of 120 solar DHW systems in France

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Introduction

As part of its "Plan Soleil" programme, ADEME (French Agency for Environment and Energy Management) has allocated subsidies for solar domestic hot water (DHW) systems from 2000 to 2004. In order to analyze the programme's impact on energy consumption and the environment, 120 solar DHW systems were monitored for a minimum period of 12 months.

This experimental campaign, run on a large scale, under the responsibility of the CSTB, had the following objectives:

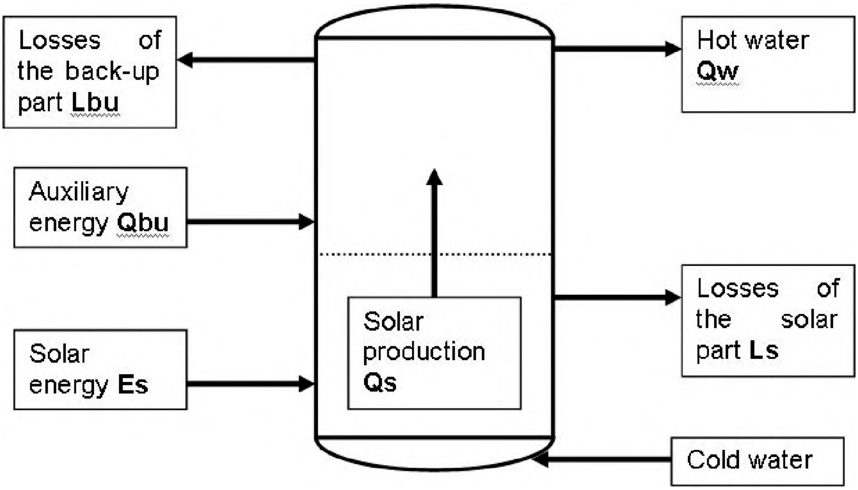
- Measurement of in situ thermal performance of operated solar water heaters in dwellings.
- Evaluation (in quantitative terms) of energy benefits as well as the environmental impact of the "Plan Soleil" programme.
- Improving knowledge on user behaviour (hot water needs, hot water tapping profiles), fixing new sizing rules for this kind of system.

The monitoring project

ADEME has funded this measurement campaign. "Electricité de France" and "Gaz de France" as well as the CSTB have also participated financially. The systems to be monitored were located in 4 regions in France, from South to North-East: Languedoc-Roussillon, Alsace, Provence-Alpes-Côte-d'Azur (PACA) and Rhône-Alpes. In each region, local operators were responsible for the installation of the measuring equipment. The 120 systems were chosen so that in each region the monitored group would be representative of the existing systems in terms of their size, back-up energy source and make.

The systems were equipped with a heat meter with volume indicator at the solar tank outlet. For solar DHW systems with an integrated back-up system (inside the solar tank), an additional energy meter was added – an electrical meter or heat meter according to the case. The operators collected the result datasheets from the users every month. 20 (5 per region) of the systems had telemonitoring equipments (level 2 instrumentation, level 1 being basic instrumentation) with acquisition and data transfer systems and additional sensors.

Of the 120 systems, only 116 were monitored over 1 year and only 93 gave credible results, due to incomplete or bad reports and measurement system breakdowns.



In order to analyse systems both with and without integrated back-up energy in a homogeneous way, we assess systems with integrated back-up energy by considering 2 parts in the tank: a bottom solar volume and a top volume heated by the back-up energy. The solar production is the energy transferred from the solar volume to the back-up volume. For preheat systems, the solar production is the energy supplied by the solar tank to the other water heater. According to the figure, the solar production Qs can be expressed as:

$$Qs = Es - Ls = Qw - Qbu + Lbu$$

An important result of a system is the energy saved, defined as the difference between the energy consumption of a reference system and the energy consumption of a solar system. For systems with integrated back-up, the back-up energy consumption is measured. For solar preheat systems, it is estimated.

The energy saved is expressed in primary energy using a conventional conversion factor (1 kWh electric = 2.58 kWh primary energy).

Avoided carbon emissions are also calculated using the following coefficients (source ADEME):

- 40 g CO_2 per kWh electrical supply not consumed for hot water
- 205 g CO_2 per kWh gas supply not consumed

– 270 g CO_2 per kWh fuel oil not consumed

The influence of various assumptions was considered for the accuracy of the results. Finally it was considered that solar production estimation is quite reliable (around 10 to 20%), whereas the energy and CO_2 estimation is slightly less reliable.

GLOSSARY

Solar fraction: energy supplied by the solar part of a system divided by the total system load (ISO 9488)

Solar production: energy supplied by the solar part of the system

Solar productivity: solar production divided by the solar collector aperture area

Back-up energy: source of heat, other than solar used to supplement the output provided by the solar thermal system (prEN 15316-4-3)

Solar preheat system: thermal solar system to preheat water prior to its entry into any other type of water heater (prEN 15316-4-3)

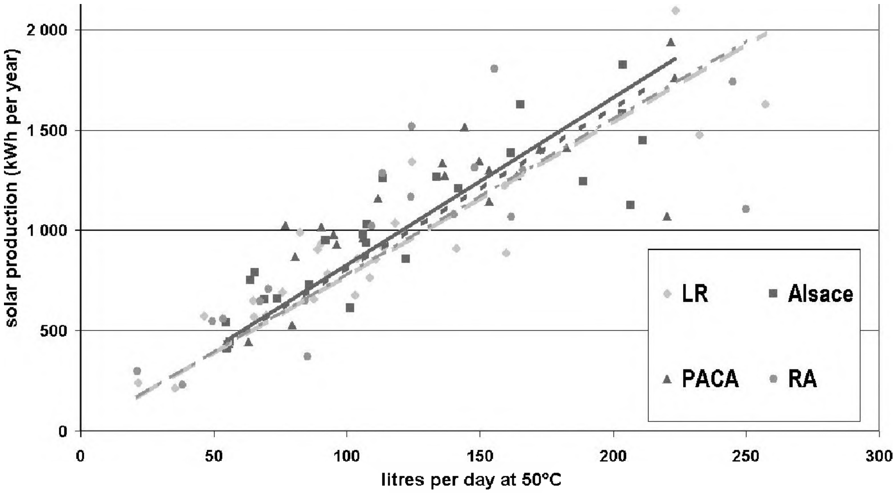
Results

The table below shows the results in the four regions. It can be noticed that the average solar fraction (between 60 and 70%) complies with expectations. However, the solar productivity is observed to about 200 kWh/m² (a little more in the PACA region) which is quite lower than the usually considered values (400 kWh/m² for example). The main cause of this low productivity is the oversize of the collector area.

Region	Average number of DHW users	Average DHW consumption at 50 °C per day	Average collector area	Average price (installed excl. subsidy)	Average yearly solar production	Average solar fraction	Average yearly primary energy saving	Average yearly avoided CO_2 emissions
Languedoc Roussillon 25 systems	3.5	111 litres 32 litres /pers.	4.3 m² 1.2 m²/pers.	4 827 €	900 kWh 210 kWh/m²	70 %	2 100 kWh	180 kg CO_2 40 kg/m²
Alsace 25 systems	3.6	118 litres 33 litres /pers.	4.9 m² 1.4 m²/pers.	5 063 €	990 kWh 200 kWh/m²	60 %	1 700 kWh	180 kg CO_2 40 kg/m²
P.A.C.A. 24 systems	3.3	132 litres 40 litres /pers.	4.6 m² 1.4 m²/pers.	4 807 €	1 160 kWh 250 kWh/m²	68 %	2 800 kWh	180 kg CO_2 40 kg/m²
Rhône-Alpes 19 systems	3.4	116 litres 34 litres /pers.	4.9 m² 1.4 m²/pers.	4 423 €	970 kWh 190 kWh/m²	61 %	1 800 kWh	210 kg CO_2 40 kg/m²

Hot water consumption is the main parameter influencing solar production. Climate or technologies are less significant parameters, as shown in the graph below where system location is pointed out.

In fact, the graph does not show a significant influence of the region (and thus of the climate) on solar production. On the other hand the solar fraction depends on the climate as shown in the previous table.



The results of the indicators "saved primary energy" and "avoided carbon emissions" depend mainly on the back-up energy used, through the various conversion coefficients.

The results do not significantly differ between systems with or without integrated back-up. However systems with integrated back-up have the inconvenience of maintaining water temperatures for an oversized volume of hot water, often sizes for 150 litres whereas 100 litres or less would be enough.

The tanks' oversize not only has the effect of increasing losses. It also causes additional back-up energy consumptions (whereas a correctly sized tank will be hot and will meet the needs, an oversized tank will be tepid and the back-up system will be activated). Tank volumes are often identical whatever the type of back-up energy, whereas for gas or fuel oil boilers, they could be reduced which would improve their performance.

Analysis of hot water tapping profiles shows large differences in hot water consumptions over a time period and from one user to another. This is a characteristic that is not sufficiently taken into account when modelling single family DHW systems.

From this sample of monitored solar water heaters it is possible to extrapolate results for the whole of France. This allows an estimation of the impact of the "Plan Soleil" programme (for solar domestic water heaters). At the end of year 2005, savings of 125 GWh primary energy had been reached and about 13 000 tons of carbon dioxide gas emissions avoided.

Conclusion

Analysis of measurements carried out on 120 operated solar DHW systems in dwellings has led to better understanding of their performances and resulting savings.

The performances observed are under the expectations but improvements are possible in terms of the sizing of the solar collectors and tank (solar and back-up volumes), the solar loop control (parameter adjustment), the control of the back-up energy system (set-point temperature) ...

The message to pass on depends on the role of each stakeholder:

For manufacturers and installers

In most cases, solar systems are oversized. By reducing their size, their cost can be lowered and they will be easier to install and integrate into existing buildings. 50 litres of hot water at 50 °C per person and per day is, on average, an over evaluated figure. Yet today, most of solar tanks available on the market have capacities from 300 litres up to 500 and 600 litres.

Improvements can be brought to the solar loop control and solar tank performances (reduce losses).

For solar domestic water heater buyers

A solar water heater covers about 60% of DHW requirements for one family. It results in savings of about 2 MWh primary energy and prevents 200 kg of CO_2 emissions in the atmosphere (the actual figures depend on the type of back-up energy used). Savings depend on hot water consumption and back-up system control, set-point temperatures in particular (preferably not over 55°C).

Reliability Improvement of Solar Thermal Systems

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Introduction

A booming market in solar thermal systems has led to a large number of operating installations in the field. But still, systems are quite complex concerning both, installation and operation. Therefore, the question of reliability is attracting more and more attention.

Due to the necessity to reduce CO_2 emission dramatically, there is a strong trend in solar thermal systems to space heating supporting systems instead of only tap water heating systems. Solar fractions above 50% are aimed at, resulting in growing collector surface areas per installation. This surface increase leads to a higher probability of overheating and stagnation. Thus, these problems are currently receiving more and more attention.

Installation and set-up of solar thermal systems are not restricted to solar enthusiasts any longer. More and more ordinary plumbers carry out installations nowadays. Moreover, installations are done in a growing number of countries, where knowledge and experience regarding installation of solar thermal systems is limited. Therefore, reliability is very closely connected to simplicity of installation and set-up. However, current high performance solar systems are quite complex, which can result in many problems of installation and set-up.

Overheating and Stagnation

One of the most frequently discussed problems is overheating during stagnation. Exposure of the heat transfer liquid to temperatures above 220 °C leads to rapid degradation of the antifreeze and subsequently to failure of the solar circuit. Another problem of overheating is that the vapour forming during stagnation penetrates into the liquid circuit where it can damage and destroy components like vents, valves, membrane expansion vessels and others.

Evaporation of the solar liquid inside the collector starts, when the circulation of the heat transfer liquid is stopped and excess solar heat of the collector cannot be dissipated any more. This can happen, for example, when heat storage capacity is exceeded and solar heat is still delivered (i.e. during summer time, especially in space heating supporting installations, when heat demand is lower than the amount of solar heat delivered) or if electrical power supply to the circulation pump fails for any raison.

In the case of sub-optimal draining performance, the vapour pushes only some part of the liquid out of the collector into the expansion vessel, thus, draining the collector partly. Some vapour might even penetrate into the piping of the solar circuit. Depending on the type of collector (i.e. vacuum tube or flat collector), the internal design (i.e meander or serpentine) and the orientation of the collector (i.e. horizontal or vertical), the draining characteristics differ significantly, leading to different quantities of remaining liquid. Due to the displacement of the liquid, the pressure in the circuit rises. The possibly remaining liquid in the collector starts boiling, and the liquid fraction of antifreeze constantly increases (i.e. the escaping vapour consists mainly of water). This change in water/antifreeze fraction continuously increases the boiling temperature of the mixture and stops when the idle temperature is reached (Fig. 1).

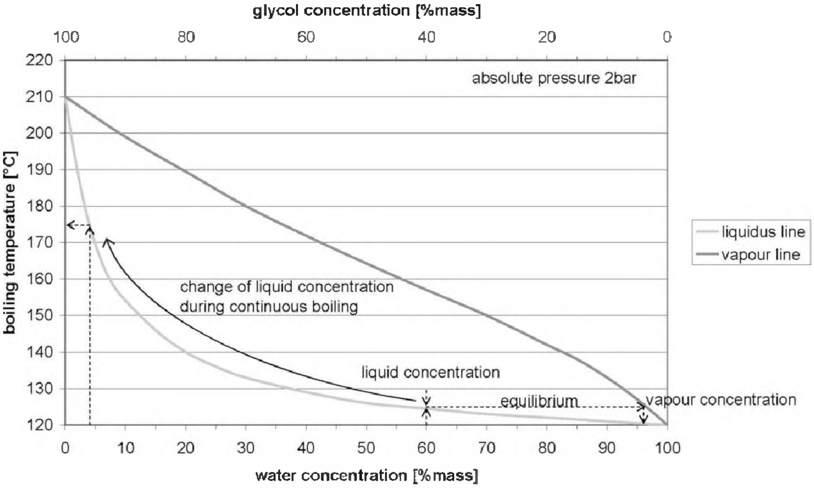

Fig. 1: Change of concentration and boiling point of the propylene-glycol-water mixture

There is a further increase in pressure due to the vapour production. This idle temperature in general is significantly lower than the value measured according to DIN EN 12975 in the middle of the collector. The lower part of the collector, where the liquid accumulates, is more affected by convectional losses. Field tests with different types of collectors showed, that degradation of the antifreeze liquid is not a problem /1/. Therefore, the real risk of overheating is limited to the problem of vapour penetrating into the piping and damaging components of the solar circuit.

Avoiding Overheating and Excessive Vapour Formation

There are various strategies to avoid the problem of overheating. The first possibility is to use easily draining collectors to avoid exposure of the liquid to idle temperatures and boiling. The most favourable draining characteristic is found in vertical serpentine flat collectors in vertical arrangements.

In many cases, however, draining characteristic is not optimal for various reasons. For example design or space requirements or hydraulic patterns in larger collector fields demand a certain orientation of the collectors pressure drop demands do not allow for serpentine absorbers in multi-collector arrangements etc. In these cases the solar circuit has to cope with vapour formation. The heat dissipation power of the circuit depends on the heat losses of the tubing. It might be necessary to add a heat dissipating vessel in front of the expansion vessel as an extra heat dissipating device. This heat dissipating vessel protects the expansion vessel and the other components of the solar pumping group from intolerable high temperatures by dissipating the heat of the condensing vapour (Fig. 2).

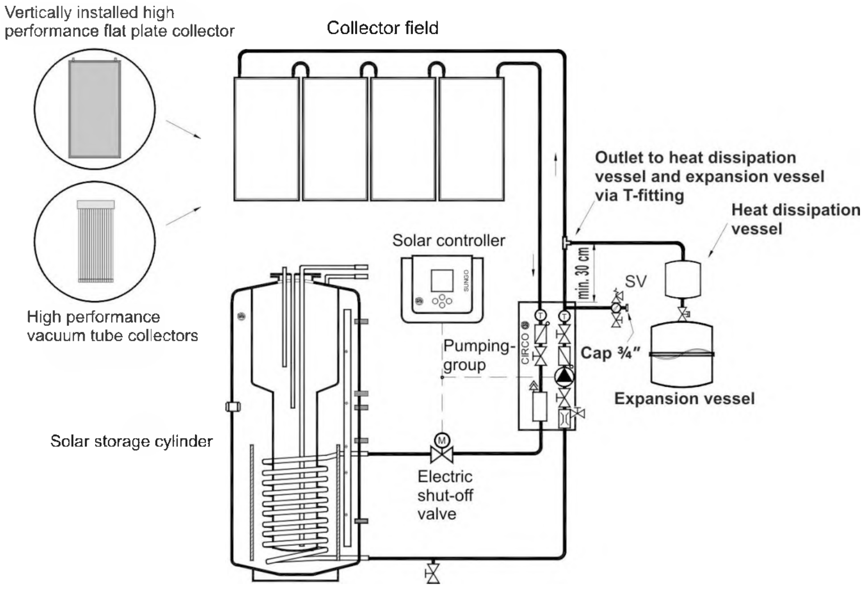

Fig. 2: Solar circuit with heat dissipation vessel

The quantity of vapour formation in the collector can be described by the maximum vapour production power. Some existing data showed values from 15 W/m² for serpentines up to 385 W/m² at 4 bar rel. pressure for vacuum tubes /1/. The maximum penetration depth of vapour into the solar circuit can be estimated, if the heat losses per length of piping and the heat dissipation performance of a possibly mounted heat dissipating vessel upstream of the expansion vessel are known. The maximum penetration depth of the vapour is reached, when the maximum vapour production power equals the heat losses of the tube and the heat dissipation performance of the heat dissipating vessel. Therefore, careful design of piping and heat dissipation vessel guarantees sufficient control of vapour penetration into the piping. Another important point is that automatic air vents are avoided or are completely left out in the sections of the hydraulic circuit which are prone to vapour exposure. This is necessary to avoid vapour losses. In these sections, it is also inevitable to use fittings which withstand vapour temperatures.

Some further proposals are less reliable, because they only work with correct working power supply and pumping devices. Therefore, they cannot ensure intrinsic safety: Reducing the efficiency of the collectors during periods of very high solar irradiation is a further approach to avoid overheating. This can be done by controlling the pump of the solar circuit in such a way, that the solar liquid in the collector reaches the maximum allowable temperature. If the temperature of the heat transfer liquid in the collector is very high, the efficiency drops significantly. Therefore, the load of the heat storage tank takes much longer, thus reducing the probability of reaching the point of stagnation of the circuit.

Other possibilities are the use of heat dissipating heat exchangers, for example existing boiler or radiator equipment during summertime or cooling of the heat storage tank during night time. The latter can easily be done by pumping the solar liquid through the collectors during night time.

Completely different approaches to overcome the problem of overheating are so-called drain-back systems. This type of solar thermal system has an intrinsic safety mechanism against overheating utilizing a self-draining effect during stagnation. The solar circuit is only partly filled with heat transfer liquid. The rest of the piping and the collector remain air filled. If the temperature in the collector reaches a certain level, the pump starts pushing the liquid upstream. This movement of liquid displaces the air into a collecting vessel, and the liquid begins to circulate. When the pump stops, the liquid drains back into the collecting vessel by gravity, and the air flows back into the collector. Thus, the heat transfer liquid is removed from exposure to solar irradiation during stagnation of the solar circuit, avoiding its thermal degradation.

Some drain-back systems run with pure water. This is only acceptable, if at no time water of the circuit is exposed to freezing conditions. However, experience shows, that this cannot be absolutely guaranteed. Maximum security concerning freezing is only provided by operation with antifreeze. The advantage of the antifreeze is that constant inclination of the piping is not mandatory, common roof passages can be used and the required accuracy of piping installation is lower.

Simplicity of Installation and Set-up

So far, installation and set-up errors have not been appropriately recognized. Only highly qualified plumbers are able to guarantee the high level of installation and set-up quality necessary for todays complex solar thermal systems. On the other hand, the increasing number of solar thermal system installations is done by a growing number of non-specialized plumbers. This conflict can be solved by a reduction of the complexity of current solar thermal installations.

One short sentence to describe this goal is:"reduce to the max". This means avoid any device which is not necessary, integrate all functions in as compact as possible ways, create ingenious ideas to improve functionality and reliability without increasing complexity.

Once more, in this case, we come back to drain-back systems. They are intrinsically safe concerning overheating. Drain-back systems do not need any heat traps, because thermosiphon effects cannot occur. Defects of this kind of device do not exist. Insufficient deaeration, which occurs sometimes in installations, is no issue in drain-back systems. Vents are not necessary. The occasionally failing membrane expansion vessels are not required, since the thermal expansion of the water is compensated by a collecting vessel or an only partly filled storage tank.

The Secusol drain-back system by Wagner & Co (Fig. 3) even goes some steps further. The concept of liquid expansion compensation has been implemented keeping simplification in mind. State of the art drain-back systems do have a collection vessel which is normally a separate component of the solar inlet. This vessel has to withstand relatively high temperatures and pressures and must be insulated. Secusol works without such a separate vessel. Instead, the diameter of the heat exchanger coil inside the heat storage tank simply was increased so that it can take over the additional function of the collecting vessel.

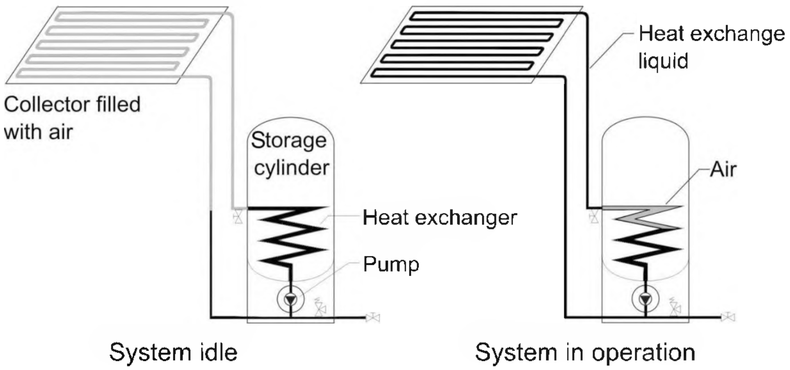

Fig. 3: Wagner & Co. drain-back system Secusol

Integrated collection vessels have been known before. However, the simplification of design, which allows for the use of weldless pipes and avoids the requirement for any additional insulation, is unique to the Secusol system. It improves reliability and at the same time reduces complexity of production and maintenance.

A side-effect of the integration of the collecting vessel was an increased heat transfer rate inside the heat exchanger coil. During operation of the system, there is a two-phase flow inside the coil. Forming a thin layer, the liquid moves very fast and highly turbulent along the inside surface area of the coil. This is favourable for the heat transfer compared to the relatively slow movement of the liquid when the coil is completely filled with liquid.

Corrosion and cavitation do not pose any problem in the Wagner & Co Secusol system. This has been shown by some investigation by the Institute of Energietechnik, TU Dresden /2/ and by a large number of field tests in Spain.

A very high level of pre-assembly and the reduction of the number of necessary components lead to a significant reduction of installation time. The installation steps related to pumping group, membrane expansion vessel and solar controller all cease to apply. All these components are either pre-assembled on the Secusol system or not required at all. The solar circuit of the system is filled by gravity only, a filling pump is not necessary. Deaeration and adjustment of the expansion vessel pressure are not needed (Fig. 4). Installation time can be reduced to 50% compared to common solar heating installations. In addition, maintenance is simplified.

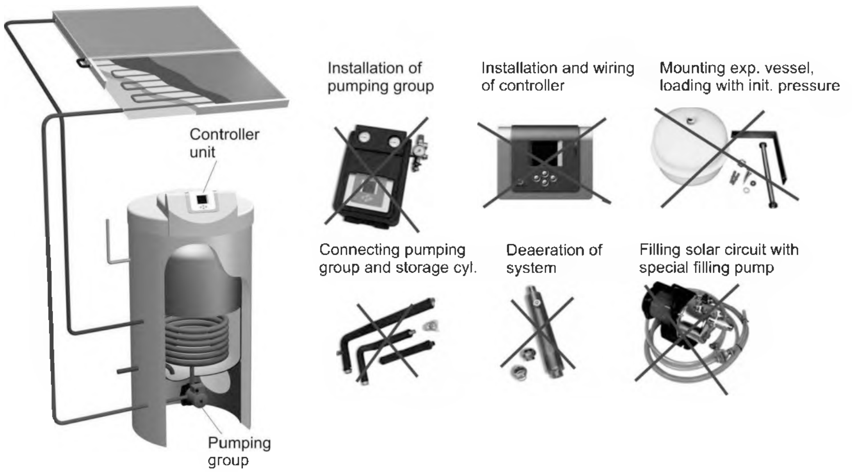

Fig. 4: Wagner & Co. drain-back system Secusol

Conclusion

Today, there is a strong demand to increase solar fractions to above 50% in solar thermal systems. This results in growing collector surface areas per installation. Possible problems concerning overheating during stagnation can be avoided by considering appropriate installation rules, even if collectors do not drain perfectly. Improved drain-back systems (for example Wagner & Co. Secusol) combine a very high level of reliability in operation and simplicity in installation, set-up and maintenance. The high degree of integration of such a system significantly reduces the required level of installer qualification, installation time and cost, thus, supporting the spread of solar thermal systems.

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Function Tests and Fault Detection for Large Solar Heating Systems

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Introduction

Solar heating systems are more complex than for instance PV systems and require a permanent function control to ensure a proper operation (*Altgeld and Mahler 99, Keilholz 05, Vogelsanger and Haller 2005*), especially if A_{col}>100 m². A few approaches to overcome this problem have been developed so far: Guaranteed Solar Gains (*Luboschik et al 97*), In-Situ Short-Term Testing (*Beikircher et al 99, Schwenk et al 2001*) and Input-Output Controller (*Vanoli 01*). All these methods have the disadvantage that they either do not cover the whole system including back-up heating or do not work on a long-term basis. Therefore, systems faults can only be detected so far by costly measurements and investigations carried out by experienced engineers, as done in the German *Solarthermie* 2000 program (*Peuser 00*). A new method has been investigated at Kassel University. The approach described in this paper aims to 1) be operated during the whole life time of a large solar heating system, 2) to be able to detect and furthermore identify faults and 3) to be inexpensive by using mainly sensors which are already installed for the system control. Details are described in (*Wiese 06*).

As shown in Fig. 1, the system control unit has been integrated in the monitoring concept. It collects the data necessary to monitor the system and, so far, transfers them to a PC mounted on site. A logical structure of the supervising system is shown in Fig. 2. At night, the measured data, which are stored as one-minute mean values, are automatically transferred to the monitoring PC at Kassel University, imported into a database and evaluated.

In a first control step, the measured values are checked for missing data. If 95% of the daily data are available in the database, a "stationary" plausibility check is carried out in a second step using different data measured at the same time. In a third step, the solar gains are checked with dynamic system simulations. At the end, the results are stored and, if necessary, warnings and alerts are generated. Plausibility checks and simulations are described more thoroughly in the next chapters.

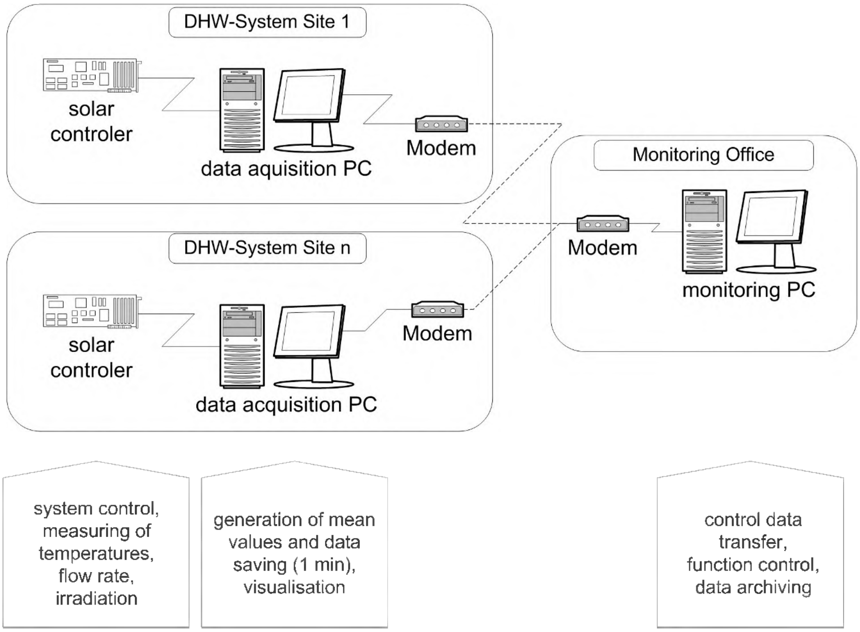

Fig. 1: Schematic of the data handling during the field tests carried out at a domestic hot water system (DHW).

"Stationary" Plausibility Checks

For the plausibility checks, the system behaviour has been reproduced through stationary mathematical algorithms and the data are scanned for faults step by step. Depending on the faults looked for, algorithms of different complexity are necessary. A cable defect at a temperature sensor is comparably easy detectable due to unreasonable measured values, whereas different data need to be combined to detect for instance the failure of a pump. Additionally, in order to test the flow rate in the respective hydraulic circuit it needs to be investigated whether the on-condition is met at that time. Fig. 3 shows exemplary the test of the UA-value of the heat exchanger in a solar heating system in a hospital in Frankfurt/M. (Germany). The UA-value has been calculated from measured values of four temperatures and the flow rate in the collector circle. The upper and the lower curves show the confidence interval for the UA-value, taking into account the accuracy of the measurements. Hereby, nonconforming components can be identified, but also creeping decreases of the heat transfer coefficients. In the example, the manufacturers specification is permanently far above the confidence limit of the measurements. Thus, a decision can be made to change or to clean the heat exchanger. If the ascertained value seems to be still tolerable, the boundaries to give an alarm might be adopted as well.

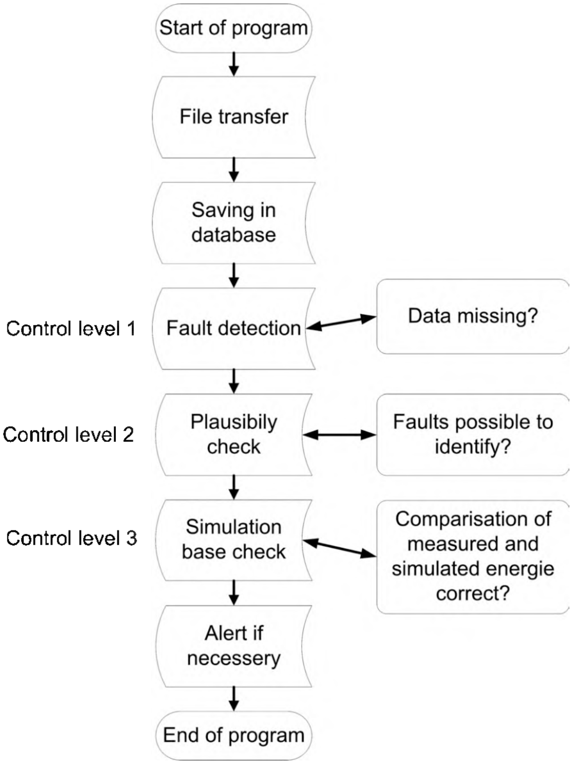

Fig. 2: Sequencing of the function control for big solar heating systems on the monitoring PC.

It could be shown that a long term monitoring is possible with some constraints using such control algorithm. Wrong operating and/or implemented controllers can be detected and partly even identified as well as poorly working pumps, heat exchangers and several hydraulic faults.

Advantages of the method are that only very few sensors are required additionally to those which are anyway necessary to control the system and that failures can easily be reported due to the connection of the monitoring PC to internet and email. A disadvantage is that reduced yields of the system cannot be quantified so far. Thus, it is difficult to decide whether measures to improve the function of the system are worthwhile. Also, identification algorithm could not be found for all conceivable system failures. Furthermore, most of the large solar heating systems are individually planned. Even after very careful adaptations of the algorithms to the respective solar heating system, some probability remains that a failure with considerably reduced solar yields remains undetected. To avoid this, a further control procedure is recommended which is based on dynamic system simulations.

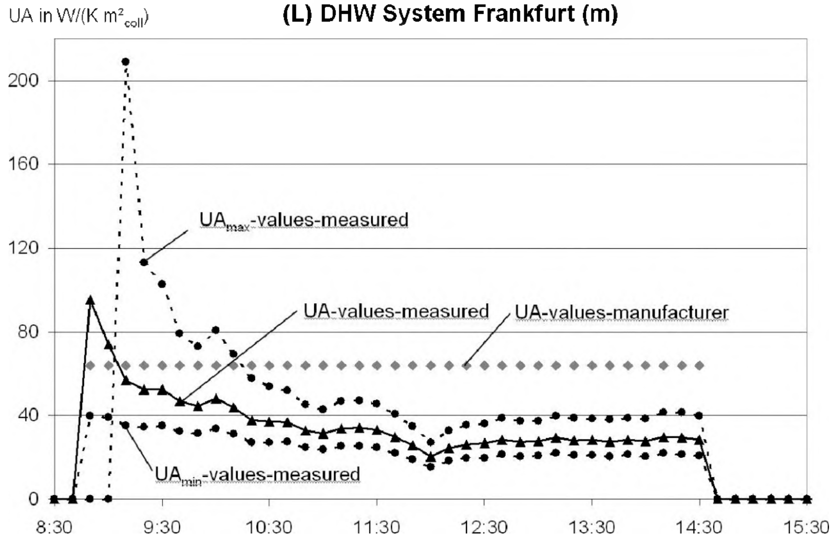

Fig. 3: UA-value of the heat exchanger in the collector circuit, derived as 10-minute mean values from measured data (dashed black line) at a large solar heating system for a typical day. The dotted lines show the upper and lower confidence limit, taking into account uncertainties of the temperature measurements of ±1K and of the flow rate of ±5%. The grey dots show the specification of the manufacturer.

System monitoring based on dynamic simulations

The aim of the proposed procedure using system simulations is to determine numerically the designed solar gain in order to compare these values automatically with the actual gain derived from measured values. This comparison indicates whether the system is operating in the respective period without important solar gain reductions, cf. Fig. 4. For the comparison, enthalpy values for charging and discharging of the storage tanks are selected.

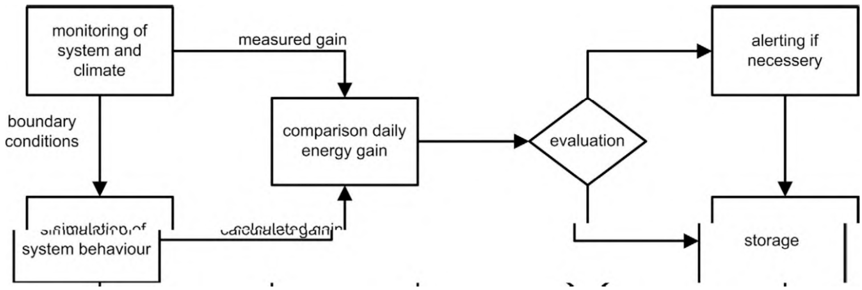

Fig. 4: Rough scheme of the simulation based system monitoring.

Actual system gain: The actual system gain can be determined using the enthalpy flow through the heat exchanger using the following equation:

$$\dot{Q} = \rho \cdot c_p \cdot \dot{V} \cdot \Delta T$$

As measured values, the flow rate as well as inlet and outlet temperatures on one side of the heat exchanger (either primary or secondary) are required. To consider sensor uncertainties, maximum errors Δv and ΔT can be estimated and considered. With an integration of the measured values over time an estimation of maximum Q_{max} and minimum Q_{min} gains can be made. Q_{max} and Q_{min} are forming a confidential range, in which the real values considering the sensor uncertainties can be expected.

$$Q_{max} = \rho \cdot c_p \cdot \left(\dot{V} + \Delta\dot{V}\right) \cdot \left[\left(T^{VL} + \Delta T\right) - \left(T^{RL} - \Delta T\right)\right] \cdot \Delta t$$
$$Q_{min} = \rho \cdot c_p \cdot \left(\dot{V} - \Delta\dot{V}\right) \cdot \left[\left(T^{VL} - \Delta T\right) - \left(T^{RL} + \Delta T\right)\right] \cdot \Delta t$$

System design yield: In order to determine the design yield of a solar heating system for a desired period (e.g. one day), the installed solar heating system including the complete control strategy has been implemented in a powerful simulation tool (TRNSYS). To reduce the effort of implementing new solar heating systems in the simulation environment, only standardized system designs have been investigated so far. The simulations are carried out with measured irradiation, ambient temperature, cold water inlet temperature and flow rate as boundary conditions. The simulations supply the cumulated enthalpy transfer through the heat exchangers.

For a validated system implementation, the determined solar gain can be considered as the design yield of a well functioning solar heating system. However, even for the determination of the modelled solar gain, uncertainties of the measurement of the boundary conditions as well as uncertainties of the numerical models need to be considered. For instance, the reliability of the simulation result depends on simplifications in the reproduction of the system, uncertainties of parameters, and the time step of the simulation and the input data. In (*Wiese 06*), comprehensive investigations have been carried out to determine the influence of various factors. Very influential are the simulation input data in the order irradiance, ambient temperature, water demand profile and cold water inlet temperature as well as the system parameters collector efficiency curve, UA-values of heat exchangers and storage tank insulation. However, with an influence on the solar gain of about 1% per 1% deviation of sensor value, the influence of the radiation is twice as high as from all the other values.

Furthermore, investigations regarding the accuracy of the storage tank initialisation proofed that the energy content of the tank is the main value to be initialised. It was found that for tank systems consisting of single tanks with a volume of 1500 litre two temperature sensors (one at each top and bottom) for each tank are sufficient for a high accuracy of the initialisation. For systems with solar fractions of up to 50%, an uncertainty of less then 0.05 kWh/m²coll was found for 90% of the diurnal simulations of the respective reference year.

Two simulations have been carried out to form the confidence interval, which is necessary for the comparison of the actual gain with the desired design gain. For the first simulations, each parameter has been chosen in a way that the solar gain is minimal. Similar to this, the second simulation led to a maximum estimation of the solar gain.

Whether a cross over of the two confidential ranges for measured and modelled solar gains occurs during an investigated period is determined automatically. In such a case, the investigated period can be judged as error-free considering all uncertainties. Even if failed components cannot be identified directly with this part of the procedure, significant system failures are detected reliably. The proposed simulation based monitoring procedure works even with lower resolution of input values, e.g. 30-minute mean values. Thus, it was possible to adapt the procedure to system data gained within *Solarthermie 2000*. The principle of the procedure is demonstrated using measured data for the solar gain of the solar heating system in Leipzig (Joh.-R.-Becher-Str.), cf. Fig. 5.

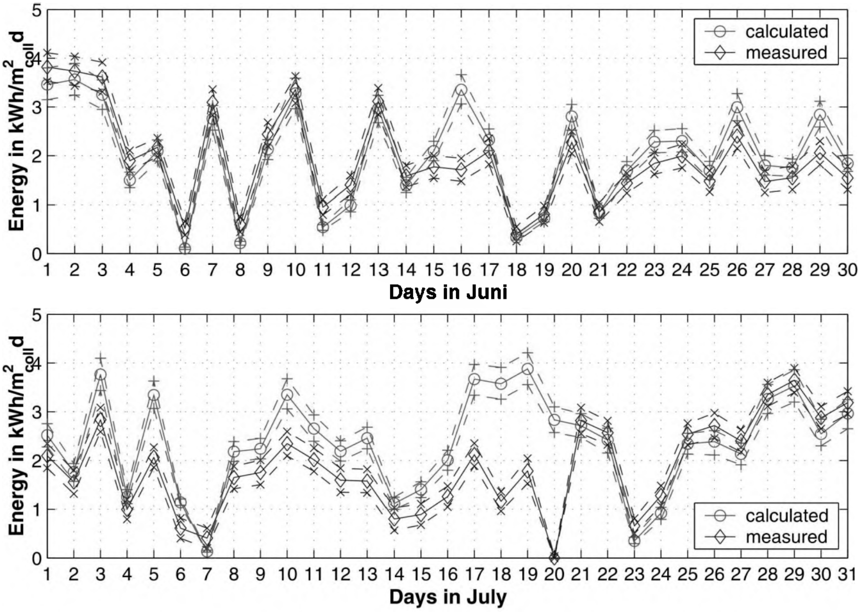

Fig. 5: Results of the simulation based monitoring procedure of a solar heating system in Leipzig.

The solid line with the rhombus symbol shows measured values of the diurnal energy gain determined at the solar heat exchanger. The dotted lines are forming the confidential range, within the real values should be located. The solid line with the round symbol shows the simulated gain. Again, dotted lines are indicating the confidential range.

During the first half of June, measured and expected values are matching quite well. In the second half of June, the measured values are significantly lower than the expected values, however, on some days both confidential intervals are crossing each other. In the first half of July, almost every day is classified as a faulty day. On July, 20th, air was released from the solar circuit, so that afterwards, the system was operating again without any problems. The evaluation of a period of some years demonstrated that uncertainties of the procedure leads to uncertain results on days with low irradiation and an expected solar gain of less than $0.5\ kWh / m^2_{Koll} d$. In opposite, a good accuracy of the proposed procedure was detected for days with high irradiation and thus days contributing significantly to the solar gain.

Summary and Conclusions

The developed method for long-term monitoring can be operated during the whole lifetime of large solar heating systems and is able to detect nearly all faults and is furthermore able to even identify several faults. This has been reached by a combination of two control algorithms, a "stationary" plausibility check of measured data and system monitoring based on dynamic simulations. The method has been tested with measured data of 1-min resolution at two large solar heating systems in Germany. Data measured in *Solarthermie 2000* are only available as 30-min mean values. Thus, those data could only be used to test the system monitoring with dynamic simulations. In all investigated systems, several minor faults have been detected, e.g. controller faults, but also severe breakdowns. It is noticeable that clogging often led to major solar gain reductions but did not lead to permanent and complete system failures. Failures, which occur only under certain operating conditions, are hardly detectable without an automated function control.

If logging and transmission of the measured data is not carried out by a PC but by cheap electronic components, the overall costs of the long-term monitoring are estimated to be in the range of 250 to 1000 €/a, which has to be compared to investments for the solar heating system of for example 100,000 € resulting in energy gains worth about 10,000 €/a. However, the virtual cost for the long-term monitoring is even lower, since the method may also contribute to save other costs for traditional monitoring and maintenance work.

Acknowledgement
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Polymeric materials for solar thermal collectors – a feasibility study

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Introduction

The scarcity of fossil fuels is beyond question – one way to save these resources is to make use of solar thermal energy for domestic hot water. So far, solar thermal collectors mainly consist of glass and metal parts. Not simply substituting materials in existing systems but developing a fundamentally new design is the objective of the research at the Fraunhofer ISE in the framework of Task 39, a task within the Solar Heating and Cooling Programme of the IEA.

Key advantages of polymers are cost as well as weight reduction, along with the benefits and cost savings associated with well established manufacturing processes and improved fastening, reduced part count, and overall assembly refinements.

Since the economic viability of solar collectors is strongly linked to the costs of the system, a decrease in the costs of the system would lead to a higher market penetration. However, also the probably changed system performance is an important element and may not be forgotten.

To consider these elements in an integrated way, the Fraunhofer ISE is currently working on the concept of a full polymeric collector, as only then the full potential of polymeric materials can be used. The talk describes results of this work.

One topic is the identification of the requirements for the polymeric materials. Important parameters are of course on one hand the absorption of solar radiation, the thermal conductivity and the heat capacity. But on the other hand one has to consider the intrinsic stress factors like UV-radiation, high temperatures and mechanical load because the systems have to reach a service life time of more than 20 years.

With the help of numeric simulations of the fluid dynamics in the collector, possible geometries are tested and optimized. The aim is to develop a layout which assures a homogeneous flow and a maximized contact area between the absorber and the heat transfer fluid.

Besides the technical view, it is also important to have a look at the economics of a new designed system to ensure acceptance and success of the technology. Here not only the material costs are relevant, but also the manufacturing technologies and their specific costs as well as the costs for shipping, handling and installation have to be considered.

Background

The need of a broader utilisation of solar-thermal energy becomes more and more obvious because of the increasing prices of fossil energy and their upcoming shortage. About 50% of the energy consumption is used for heating. Here is the biggest potential for the substitution of fossil energy sources by renewable energy, solar- thermal energy especially. A rapidly growing market and production is needed in order to achieve a significant share rapidly and in time.

But how to provide these huge areas of solar collectors? Most common is nowadays the use of copper absorbers for flat-plate solar collectors. The copper content in conventional flat plate collectors varies between 2 and 6 kg/m^2.

Taking into account the copper used in piping and heat exchangers/heat stores, we assume 5 kg/m^2 collector as good estimate. Each m² collector delivers typically 300 kWh/year. Hence 1 MWh/year corresponds to 16.5 kg copper.

Thus, to increase the annual world production of solar heat to 1% of the present human energy consumption, an installation of 22 mill. tons of copper is required. The annual production of copper world-wide is approx. 15 mill. tons. Besides that, the market-price for copper already increased very much during the last years. The need for new materials is obvious. Aluminium, steel and other metallic materials will be used more. Polymeric materials have to be considered as an alternative, too.

The major advantages using polymeric materials are: low material cost in general (there also exist very expensive high performance polymers), low weight, and low manufacturing costs. The latter property is perhaps the most important factor when choosing polymeric materials for a specific application. Using polymers, at least in large scale production, complex integrated structures can be manufactured in a single step through e.g. injection moulding or extrusion.

The R&D in polymer-technique created numerous new materials, components and manufacturing technologies during the past decades. Their application in solar technologies is still very limited, since the applicability and the durability of these materials is uncertain. R&D efforts are needed to realise the full potential of polymers to reduce life-cycle solar energy conversion costs. Problem areas which are identified are the interactions of a material with, or its response to the total environment; photo-degradation; permeability, adhesion; surfaces and interfaces; thermo-mechanical behaviour; dust adhesion; and abrasion resistance. Other points are the lower thermal conductivity and mechanical stability of polymers.

Polymeric materials can play a key role in the future development of solar energy systems. Polymers offer potentially lower costs, easier processing, lighter weight, and greater design flexibility than materials in current use.

Approach

Within Task 39 of the IEA Solar Heating and Cooling Programme we want to develop all-polymeric collectors. That means that the design of the collector has to be reengineered in a way that it is optimized to the material properties.

In a first step we have to think about the functionality and requirements of this new kind of collector because the construction has to be quite different to the standard design of collectors with copper-based absorbers and fluid tubes. Due to the lower thermal conductivity of the polymers we have to enlarge the contact area between absorber layer and fluid and minimize the thickness of materials which have to be passed by the heat flow. Another point is the processing and production. To be able to use low cost processes like extrusion specific geometrical constraints have to be considered.

In addition we have to identify the potential candidate polymers and their specific strength and weaknesses. Here a look on the physical and chemical properties of different polymers is necessary to find out if commodity materials are able to stand the requirements or if high performance polymers are necessary. Another point is the question how many additives are necessary to improve the materials performance.

On the other hand we have to change the design of the collector to take the materials and processing into account. Here we use numerical simulations to compare different collector geometries regarding the fluid dynamics and possibilities of placing a special absorber layer. We can also identify the influence of material parameters like thermal conductivity or system parameters like flow rate. Another possibility of the numerical simulation is the investigation of extreme service conditions like the stagnation temperature inside the collector. With the help of these calculations we can specify the material requirements for different collector designs.

Potential materials for polymeric collectors

Although the approach for developing polymeric collectors is rather an approach from the material side, some requirements for the use in domestic hot water heating and possibly heating support should be met, regardless of the material used. Very important is that temperatures of up to 90–100 °C are tolerated. In addition, UV-stability is essential, as well as chemical resistance to the heat transfer fluid. Other properties that are important in the end are e.g. the transmittance, heat conductivity, and absorption.

In the following table, some thermoplastic polymers and a section of interesting properties are presented. The values given are a compilation of various sources and a possibility for a first rough estimation and overview. The first four polymers (PE LD, PE HD, PP, PVC) are commodity plastics with rather low prices whereas PC and PPO are higher performance engineering polymers and accordingly more expensive. It is important to note that the upper temperature for steady use is given and not the short term working temperature. However, this does not yet say anything about the service life time of a product made of this material, since when used in a collector, various stress factors are combined. The heat deflection temperature mentioned is defined as the temperature at which the polymer sample reaches a certain bending under a defined pressure.

Most thermoplastics, and all mentioned in the table, are extrudable, so the advantages of a well-known, effective continuous process can be used. The processing through extrusion imposes some constraints on the cross section and shape of the collector, but these are not necessarily a disadvantage but can be considered in the choice of a design. With injection moulding, another well-established possibility for the processing of these thermoplastics is available.

Name	Abbreviation	Young's modulus	τ	UV-Stability	Heat conductivity	Glass transition temperatur	Maximum constent working temperature	Heat defelction temperature
		[N/mm²] = [MPa]			[W/mK]	[°C]	[°C]	HDT/A (1,8 Mpa) HDT/B (0,45 Mpa) [°C]
Polyethylene low density	PE LD	>150 - 200	translucent	limited	0,31	110	70 - 80	not applicable 41
Polyethylene high density	PE HD	1000	translucent	limited	0,42 - 0,43	135	80 - 90	49 70 - 86
Polypropylene	PP	1300 - 1450	translucent	limited	0,22	163	90 - 100	55 85 - 95
Polyvinyl chloride	PVC	2000 - 3000	opaque	no	0,15 - 0,16	80	70	61 69 - 75
Polycarbonate	PC	2200 - 2400	clear	limited	0,21 - 0,24	140 - 148	130	128 137
Polyphenylene oxide	PPO	2250 - 2300	opaque	no	0,19 - 0,22	148	105	115 130 - 135

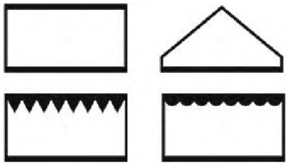
Selected polymers and their properties

However, it does not seem to be possible to find one polymer that could fulfil all the above needs as it is. Thus, one has to look for possibilities to modify polymers in order to fit them into the desired scheme. With additives, almost any modification can be done, but it is important to have a look at the prices for the additives because they might heavily increase the price for the collector material. Additives might be utilized to increase the heat conductivity, as well as the heat stability. Additives can be used as a protection against UV-radiation if no special UV-screen on top of the polymer is used.

One advantage of polymers as a new material for solar thermal collectors is the low price. Thus, one has to consider the raw material polymer price on the one hand, and the resulting needs for additives and the respective prices on the other hand. It might be more feasible to chose a higher priced polymer, if fewer additives are required in this case.

Nevertheless, not only the price for material and processing, but also the efficiency and thus the energy yield have to be considered, as these will be, due to the lower heat conductivity, lower than in conventional collectors. How this matter can be allowed for is treated in the following.

Numerical simulation of collectors



Possible variations of the extrusion conduit to improve the heat exchange.

For the analysis of the fluid dynamics and the heat transfer of the absorber, COMSOL Multiphysics is one tool of choice. It is a modelling package for the simulation of any physical process you can describe with partial differential equations. A key advantage is the possibility of coupling miscellaneous simulation applications. A subsequent structural mechanical analysis can also be carried out with the same programme, even the same model.

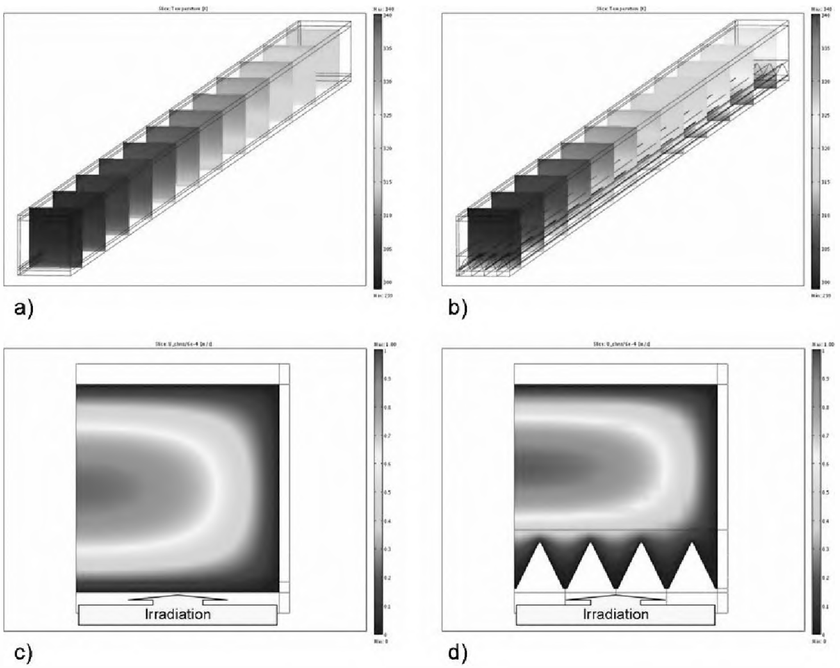
In order to use the full advantage of the material performance, designs which can be manufactured in a single step by extrusion are examined. This aspect limits the variation of the geometry of the conduit.

Due to the lower heat conductivity of the polymers, the absorbers need to be flown through on the whole area. Assuming that the mass flow per hour and collector area is the same as in a conventional collector with copper absorber (20 kg/h*m²), the speed of flow is very small. Therefore and due to the fact that the absorber ducts are assembled parallel, the pressure drop is negligible.

Therefore the main focus is on the heat exchange between absorber and fluid. With the extrusion technology there is virtually no limitation of possible conduit designs. It is comparatively easy to change form and shape of the flow channels or to modify the boundary conditions in numerical simulations for optimizing the product. So it is possible to save a lot of time and money compared to the conventional way of prototyping and testing new designs.

No specific polymeric material was considered for the beginning. The results are not of absolute character but are fine to compare the respective conduit designs, examples can be seen in Fig. 1. Later on it will be no problem to change the parameters according to the chosen materials and get reasonable results that can be verified by a prototype test run.

Example of a computated simulation



Two different geometries of an absorber conduit with temperature and flow distribution. Picture b) shows the temperature distribution along the conduit and picture d) shows the flow speed distribution of an even cross section of a modified duct. Contrary to reality, the absorber duct is only displayed in half and is turned upside down so that the irradiation gets in from below. That is in part due to a more effective simulation and has no effects on the result. The pictures on the left hand side show the temperature and flow speed distribution in the reference duct.

The example in Fig. 2 shows (pictures a) and b)) that the heat exchange between absorber layer and fluid is much better in the absorber duct with the structured conduit, which means a better collector efficiency. One can also see in pictures c) and d) that in both designs is only very low flow in the region near the absorber layer.

The simulation was carried out on a LINUX based AMD Athlon 64 Dual Core Processor with 2.2 GHz and 4 MB RAM. The mesh in case a) consists of about 8000 elements with 180,000 degrees of freedom. Solving time is about 25 minutes.

Outlook

We want to go on with the evaluation of candidate materials and start accelerated and real time tests on selected materials to identify the most promising ones. Then the aim is to build demonstration collectors with these materials to perform further tests, including tests of the durability and efficiency. We would appreciate to do this work in good contact with industrial partners.

With the help of numerical simulations we want to calculate and compare the energy output of different designs and material combinations and optimize the design to develop a collector with good efficiency and price. Here we want also to identify the load levels at certain service conditions. Besides that different kinds of absorber coatings and their way of application shall be investigated.

Acknowledgements

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Ageing of Solar Thermal Collectors

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Introduction

Solar thermal collectors are one of the basic components of solar thermal systems. However, the thermal performance of solar collectors may be reduced over the years by ageing effects. In order to quantify ageing and its impact on the thermal performance of solar thermal collectors, thermal efficiency tests have been carried out with 15 collectors in new and used state. The selected collectors represent a good cross-section of collector types available on the market in the years 2001 and 2002. The investigation comprises 13 flat plate collectors with and without antireflective coating of the glass cover, with different insulation materials and different selective coatings as well as two evacuated tube collectors working according to the direct principle. One evacuated tube collector is a so-called Sydney-Collector with a cylindrical absorber with CPC reflector (CPC: compound parabolic concentrator). The other one also works according to the direct principle, with the collector loop heat transfer fluid being transferred through the header with a so-called "wet connection". Each of the tubes of this type of evacuated tube collector is equipped with a selective coated absorber fin.

The thermal efficiency of the collectors was previously determined in 2001 and 2002 in new state. Hence the characteristic collector efficiency parameters for the new collectors are known. Afterwards the collectors have been exposed outdoors for a 3 year period to normal weather conditions. During that time the collectors were not filled with a heat transfer fluid. Therefore the conditions were similar to the operating state "stagnation" where no usable heat is removed from the collector and hence very high absorber temperatures are reached. After the exposure the thermal performance of the collectors was determined again in 2005. Like the performance tests of the collectors in new state, this was done by an outdoor test according to EN 12975–2 using the quasi-dynamic test method for the determination of the characteristic collector efficiency parameters.

The paper will present a comparison of the characteristic collector efficiency parameters for the new and the exposed (aged) collectors. Furthermore it will be shown how the changes in the collector efficiency parameters due to ageing will influence the yearly energy gain and the fractional energy savings of a typical solar domestic hot water system.

1. Impact of exposure on characteristic collector efficiency parameters

In the following the changes of the collector efficiency parameters due to the 3 years exposure will be presented and discussed. First the resulting changes of the conversion factor η_0 and the heat transfer coefficients of the 15 solar thermal collectors are presented. For a better assessment of the exposure impact on the heat transfer coefficients a_1 and a_2, the effective heat transfer coefficient $a_{eff}(50K)$ at a temperature difference ΔT of 50 K (between average fluid temperature and ambient temperature) was determined according to equation 1.

$$a_{eff}(50K) = a_1 + a_2 \cdot \Delta T \qquad \text{with} \, \Delta T = 50K \tag{1}$$

1.1 Conversion factor

Fig. 1 shows the conversion factors η_0 of the 15 collectors in new state and after the exposure. Nearly all of the collectors show a slight decrease of the conversion factor.

As the conversion factor is mainly dependent on the transmittance-absorbance product, it is possible that the decrease does not necessarily result from a reduction in absorbance of the selective coating, but possibly from a reduction of transmittance of the transparent collector cover. Former investigations /1/ show that dust deposits on the cover are often the reason for a lower transmittance and that this problem can be solved with a thorough cleaning of the collector cover. During the exposure no special cleaning had taken place but deposits on the collector cover were partly removed by natural rain. Prior to the thermal efficiency tests the collectors were washed off. However, a special cleaning with cleaning agents, as it was done in the above mentioned investigation, was not carried out.

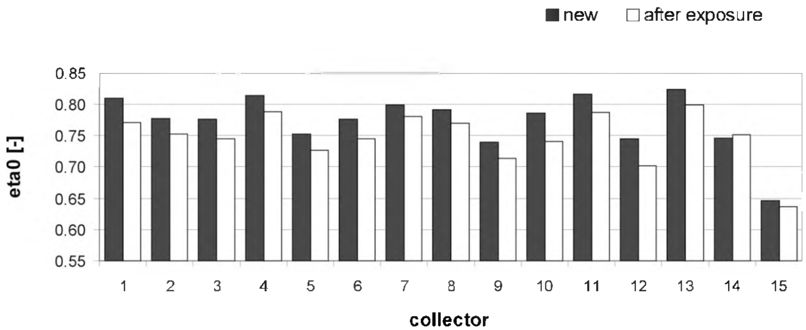

Fig. 1: Conversion factors η_0 of the 15 tested collectors in new state and after the exposure

The comparison of the conversion factors in new state and after the exposure results in an average reduction of the conversion factor of –2.6% (absolute). The entire range of the absolute reduction comprises +0.5 to −4.5%. Regarding the flat plate collectors, collector no. 7 shows the smallest reduction of −1.8% (absolute). The evacuated tube collectors 14 and 15 show only very slight changes in the conversion factors. Collector no. 15 with its absolute reduction of −0.9% is clearly under the average of −2.6%. Regarding collector no. 14 a slight increase of the conversion factor of +0.5% can be observed, which is however in line with the measurement accuracy.

1.2 Effective Heat Transfer Coefficient

All collectors show only very small changes in the effective heat transfer coefficients $a_{eff}(50)$. Considering the power curves of the collectors in new state and after the exposure, a parallel curve progression can be observed in most cases, as can be seen in Fig. 2 for collector no. 3. Hence no significant impact on the effective heat transfer coefficients can be observed due to the exposure.

The power curves are based on the measured results and were plotted according to EN 12975–2:2006, annex D, chapter 3 for a hemispherical irradiance of $G^* = 1000\ W/m^2$.

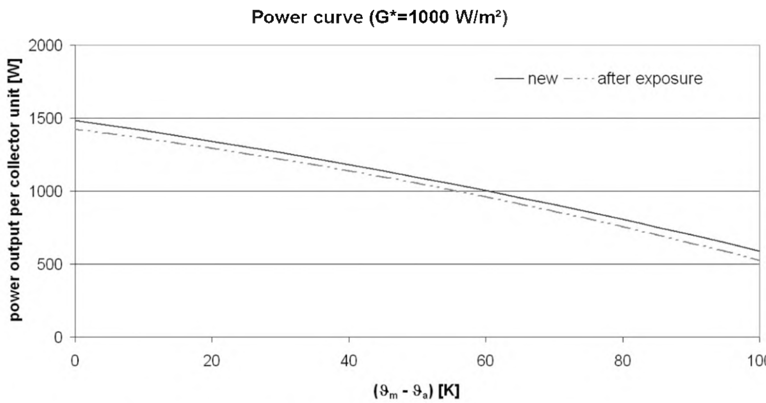

Fig. 2: Power curves of collector no. 3, in new state and after the exposure

2. Reduction of thermal efficiency due to ageing

In order to be able to quantify the impact of ageing on the energy gain of the solar thermal collectors, calculations with the simulation program TRNSYS have been carried out. This was done for a solar domestic hot water heating reference system in such a way, that only the collector efficiency parameters for the collector were changed.

Based on the collector efficiency parameters determined for the new and the exposed (aged) collectors, the energy output for each collector and the auxiliary heat demand $Q_{aux,net}$ required for a complete coverage of the hot water demand were calculated.

For that purpose a reference system for solar domestic hot water heating with the following specifications was used:

collector:	South orientation, inclination 45°
hot water demand:	200 litres/day, tapping profile: 7 a.m. 80 litres, 12 a.m. 40 litres, 7 p.m. 80 litres hot water temperature: 45 °C cold water temperature: 10 ± 3 °C yearly hot water demand: 2945 kWh
collector and collector circuit:	collector area: 5 m² flow and return pipe 10 metres each, located inside
store:	total store volume: 300 litres ambient temperature: 15 °C auxiliary heating: 15 kW, volume flow: 1292 litres/h domestic hot water set temperature: 52.5 °C
weather data:	test reference year Würzburg annual irradiance in collector plane: 1231 kWh/m²

As a result of the simulations the fractional energy savings f_{sav} for a typical solar domestic hot water system were determined according to equation 2.

$$f_{sav} = \frac{Q_{conv,net} - Q_{aux,net}}{Q_{conv,net}} \cdot 100\% \qquad (2)$$

$Q_{conv,net}$ represents the yearly heat demand of a conventional (non-solar) domestic hot water system required in order to cover the same load. It amounts to 3589 kWh and is composed of the annual hot water demand of 2945 kWh and the heat losses of the store of the conventional system with 644 kWh.

Fig. 3 illustrates the fractional energy savings f_{sav} resulting from system performance simulations with the collector efficiency parameters determined for the 15 collectors in new state and after exposure.

Fig. 4 shows the resulting relative decrease in the fractional energy savings for the 15 collectors due to the exposure. What is indicated on the Y-axis as "relative change" means the percentage of the reduction in comparison to the initial value of f_{sav} prior to exposure.

The average reduction of the fractional energy savings is about –2.4% (relative) over the entire investigated three year period. In order to point out this effect in more detail two examples are presented in the following.

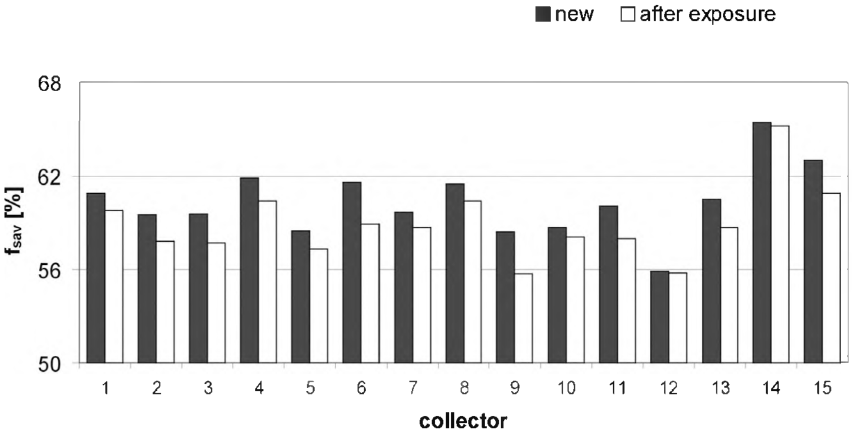

Fig. 3: Fractional energy savings prior (new) and after exposure

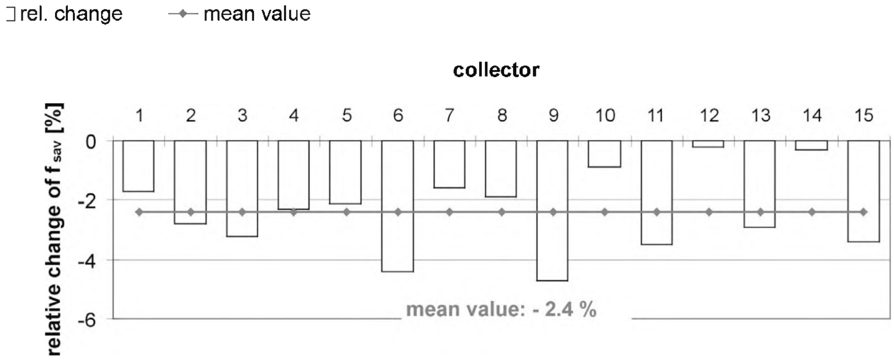

Fig. 4: Relative decrease of the fractional energy savings f_{sav} in percent

The subsequent calculations are based on the heat demand of a conventional (non-solar) domestic hot water system of 3589 kWh per year (without taking into account boiler efficiency and primary energy equivalent). With fractional energy savings of, for example 55 % (which corresponds to a saved heat quantity of 1974 kWh per year) a reduction of f_{sav} to 53.7 % (which corresponds to a relative reduction of –2.4 %) would mean that the auxiliary heater has to deliver 47 kWh per year more conventionally produced heat due to ageing of the solar collectors.

With regard to collector no. 9, that shows with –4.7 % the highest deterioration, this means that 97 kWh of conventionally produced heat are additionally required per year due to ageing of the collector.

However, on the other hand half of the collectors show a performance degradation that is below the mean value of –2.4% and therefore the increase of required conventional heating energy for a system with these collectors would be less than 50 kWh per year.

Conclusion

The results of the investigation show that even after three years of exposure with high temperature stress the thermal efficiency of the collectors was not significantly reduced. In this context it has to be considered that the collectors were exposed outdoors to normal weather conditions but not connected to a circulating heat transfer fluid that usually cools down the collectors. This way of performing the outdoor exposure leads to higher absorber temperatures and therefore to an increased temperature stress, as it would be the case under real operation conditions of the collectors in a solar thermal system.

In order to quantify the ageing effects that would occur after a certain operation period it is necessary to find a relationship between "real" operation and exposure time as well as conditions.

In order to obtain further knowledge about the ageing behaviour of solar collectors it would be helpful to carry out again thermal efficiency tests of the investigated collectors after approximately three or four years of additional exposure.

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http://www.itw.uni-stuttgart.de/~www/ITWHomepage/TZS/Lit_TZS.html

Note

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High-Efficiency Flat-Plate Solar Collectors Based on Selective Glazing

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INTRODUCTION

Many future applications of solar thermal energy, like space heating with high solar fraction and solar heat for industrial or cooling processes, will require high collector efficiencies at temperatures above 80 °C and/or at low irradiance. At the same time it is advantageous, at least for central and northern European climates, to install a collector type which is able to use the diffuse fraction of solar radiation. Today's evacuated-tube collectors (ETC) fulfill both requirements, but they are still quite expensive. Flat-plate collectors (FPC) are inexpensive and make use of diffuse radiation, but the efficiency of the currently available products is not satisfactory for the mentioned applications. We suggest to raise the performance of FPC for operation at high values of $\Delta T/G$ by introducing glass covers with selective coatings into solar thermal technology.

"Selective glazings" with low-emission coatings for suppressing radiative heat losses are well established for windows. In a double-glazed flat-plate collector, a low-e coating is highly beneficial for reducing the heat losses through the glazing. According to our calculations, this construction has the potential for performance values in the range of state-of-the-art evacuated-tube collectors.

In the following, we describe the basic idea of high-efficiency flat-plate collectors, and discuss the results of our theoretical simulations. The construction of a first prototype is explained, and experimental results are analyzed. An outlook on future improvements is given.

BASIC IDEA

The key for improving the thermal performance of flat-plate collectors at elevated values of $\Delta T/G$ is to increase the thermal resistance of the transparent cover. As a first step, it is helpful to add a second glass pane and to use anti-reflective (AR) coatings for the four glass surfaces (cf. /2/). An argon filling in the gap between the glass panes further lowers the convective losses.

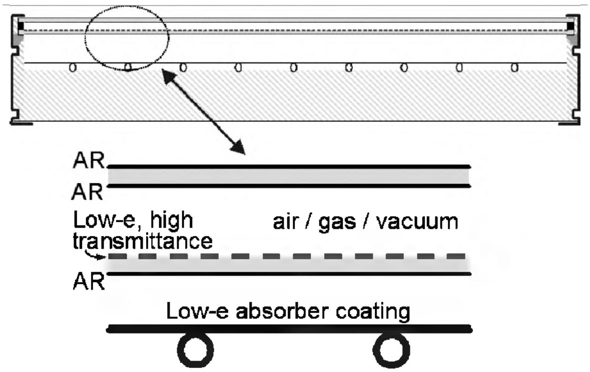


Fig. 1: Principle of high-efficiency flat-plate collector (AR: anti-reflective surface).

Nevertheless, according to our simulations (see following section), the crucial improvement is to introduce a low-e coating of the glazing in order to suppress the radiative heat losses between the glass panes. The construction of the resulting highly-efficient flat-plate collector (HFC) is shown in Fig. 1.

How many low-e coatings for the glazing are advisable, and which is the best position? The radiative heat flux between two infinite parallel plates is given by (see any textbook on heat transfer):

$$\dot{q} = \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \sigma \left(T_1^4 - T_2^4 \right) \tag{1}$$

If both of the two parallel plates 1 and 2 (temperatures T_1, T_2, emissivities ε_1, ε_2) behave like blackbodies ($\varepsilon_1 = \varepsilon_2 = 1$), the fraction in eq. (1) becomes unity; if one of the plates has a selective coating with $\varepsilon = 0.05$, the fraction is reduced by a factor of 20. But if both plates are selectively coated with $\varepsilon = 0.05$, the improvement over one selective coating is only an additional factor of two.

Hence, a second low-e coating on the glazing would not distinctly reduce the thermal losses of the collector, on the contrary: as low-e coatings will always lower the solar transmittance of the glass pane, only the first one can be expected to have a positive influence on the collector performance.

Consequently, a single low-e coating is the best choice. In order to achieve the maximum effect, this coating is on the upper side of the lower glass pane. This ensures, together with the selective absorber, that in each gas gap there is one selective coating which effectively suppresses radiative heat losses.

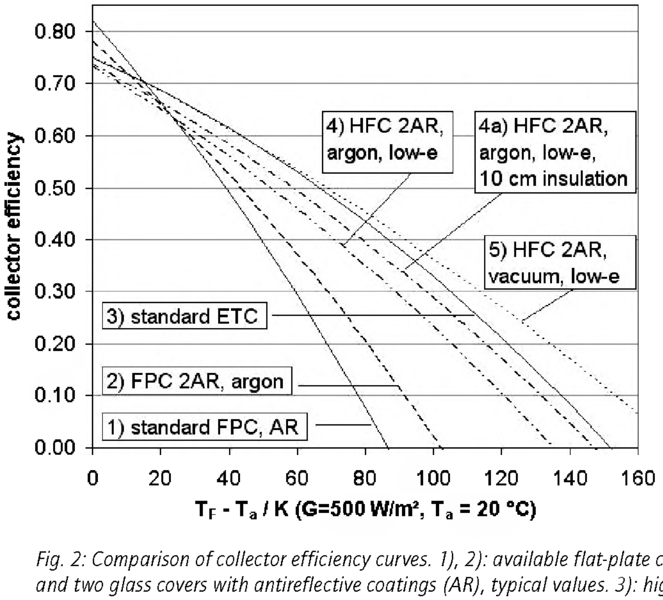
Theoretical Potential

Fig. 2 shows the influence of different measures to raise the efficiency of FPC. The collector efficiency curves are given for an irradiance of 500 W/m² and an ambient temperature T_a = 20 °C. By this, we take into account that situations with high diffuse fraction or high incidence angle of solar radiation are quite common, at least in Central and Northern Europe. In our point of view, the often-mentioned values of 800 or 1000 W/m² occur too seldom to be representative for a whole year.

For a comparison of the collectors at higher temperatures, it is helpful to regard the heat-loss coefficient $a_{60} := a_1 + a_2 * 60$ K at a temperature difference of $\Delta T = 60$ K between the fluid inside the collector (T_F) and the ambient air (T_a). The values of a_{60} are given in Table 1.

The curves no. 1 (standard FPC with AR glass, a_{60} = 4.4 W/m²K), 2 (FPC with two glass panes, AR, and argon filling, a_{60} = 3.4 W/m²K) and 3 (good ETC, a_{60} = 1.8 W/m²K) represent values of typical available collectors.

The curves no. 4, 4a and 5 for highly-efficient flat-plate collectors (HFC) were calculated by us. The underlying optical properties of the low-e coating are only slightly better than those of available coatings.



Coll. no.	a_{60} / W/m²K
1	4.4
2	3.4
3	1.8
4	2.27
4a	2.02
5	1.80
6 see Fig. 4	2.5

Table 1: Heat-loss coefficient a_{60} of the investigated collectors.

Fig. 2: Comparison of collector efficiency curves. 1), 2): available flat-plate collectors (FPC) with one and two glass covers with antireflective coatings (AR), typical values. 3): high-quality evacuated tube collector (ETC), typical values. 4), 4a), 5): high-efficiency flat-plate collectors (HFC), values calculated by ISFH.

Collector 4 has two AR glass panes, with an argon filling in between, and a low-e coating. Comparing collectors 2 and 4, it can be seen that the performance of double-AR-glazed FPCs for elevated $\Delta T/G$ is improved significantly by a low-e coating. The overall heat-loss coefficient a_{60} drops from 3.4 W/m²K to 2.27 W/m²K.

Collector 5 is an HFC with evacuated glazing. Although evacuated glazings are not yet a mature technology (for the present state see e.g. /3/, /4/), it is helpful to take them into account and to assess their potentials. With collector 5 (a_{60} = 1.80 W/m²K), the performance of today's ETCs is equalled, and even surpassed for higher temperatures.

The better the thermal insulation of the transparent aperture of the collector, the more important is the backside insulation. Hence, it is possible to further increase the thermal performance of collectors 4 and 5 by improving the backside insulation. While the calculation for these collectors is based on a standard mineral wool (thickness 5 cm), collector 4a has a doubled thickness (or halved thermal conductivity) of the backside insulation, the rest of the construction being identical to collector 4. Collector 4a (a_{60} = 2.02 W/m²K) performs almost as well as the ETC, without the need for an evacuated glazing.

The contribution of the backside losses to the overall heat-loss coefficient may be assessed as follows. For the standard FPC (no. 1), the thermal conductivity of mineral wool for T = 80 °C (ΔT = 60 K) is $\lambda \approx 0.044$ W/mK. With a thickness of 50 mm, the backside heat-loss coefficient $a_{60,back}$ is about 0.88 W/m²K, which is 20% of a_{60} = 4.4 W/m²K. When a_{60} is halved to 2.2 W/m²K (which is comparable to the HFCs 4 and 4a), the fraction of the backside losses increases to 40%. Correspondingly, the importance of improving the backside insulation is doubled.

First Prototype: Construction

In the summer 2006, we built and tested a first prototype (cf. Fig. 3). We used commercially available components only in order to accelerate our procedure. The collector is double-glazed with air in the gap. The spacers between the glass panes are made of wood, again in order to have a quick and simple solution. The upper glass pane has AR coatings on both sides. Nevertheless, its solar transmittance is only 0.915 approximately, which is about 4% below high-quality AR-glass. The lower glass pane is an available low-e coated glass (K-Glass, Pilkington) with an emissivity ε = 0.24. As K-glass was developed for window glazings instead of collectors, it has a high iron content, which in turn leads to a comparatively high absorption of solar radiation inside the glass, and hence to a reduced thermal performance of the collector. Moreover, the low-e coating is not best suited for solar collectors, as it was not optimized for maximum solar transmittance. Deviating from the principle depicted in Fig. 1, the lower glass pane does not have an AR surface on its lower side.

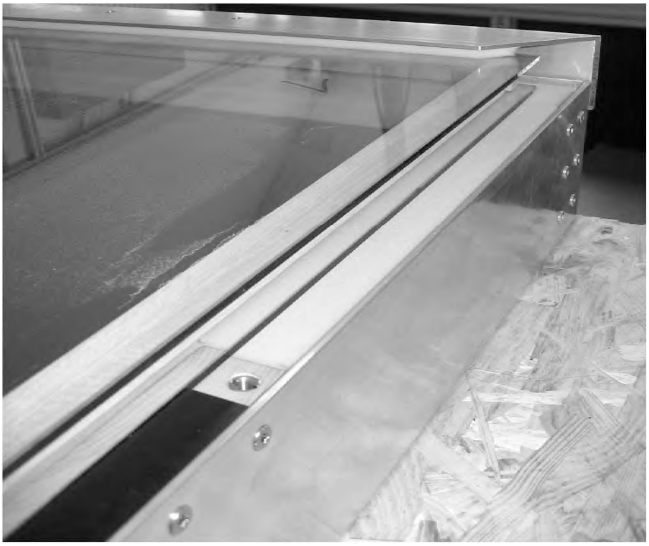


Fig. 3: First prototype of high-efficiency flat-plate collector (HFC), built at ISFH in 2006

We used a copper absorber with laser-welded tubings and a highly selective absorber coating, of which we measured $\alpha = 0.945$, $\varepsilon = 0.087$. The coefficient U_{int}, which describes the heat transfer between absorber and fluid (cf. /1/), equalled 63 W/m²K (local measurement). The aperture area A_a of the collector was 1.941 m².

The collector box is similar to commercial products. It is made of aluminium. Mineral wool with a thickness of 50 mm was used as backside insulation. Heat bridges between the glass panes and the frame of the collector were minimized.

Experimental Results and Discussion

In an outdoor performance measurement according to EN 12975, the conversion factor of the prototype was $\eta_0 = 0.648$, and a_{60} was 2.5 W/m²K. The measured collector efficiency curve is given in Fig. 4, together with some of the curves discussed above.

It can be seen from Table 1 that the heat-loss coefficient a_{60} of our first prototype is already much lower than that of commercially available flat-plate collectors with double-AR glazing and argon filling (collector 2). Even more important, a_{60} of this first prototpye is already very close to the values of the theoretical HFCs and of good existing ETCs.

The conversion factor of our collector is not yet competitive, but a much higher optical efficiency of HFCs is possible without any R & D, just by using high-quality components of today's state of the art. These include:

- a high-quality AR glass with solar transmittance of 95 to 96% instead of 91.5%,
- a low-iron glass pane as a substrate for the low-e coating,
- an AR coating on the lower side of the low-e glass pane.

Our simulations show, that even with the low-e coating used in our experiment (which shows a comparatively low solar transmittance), $\eta_0 \approx 0.70$ is achievable when the mentioned measures are taken.

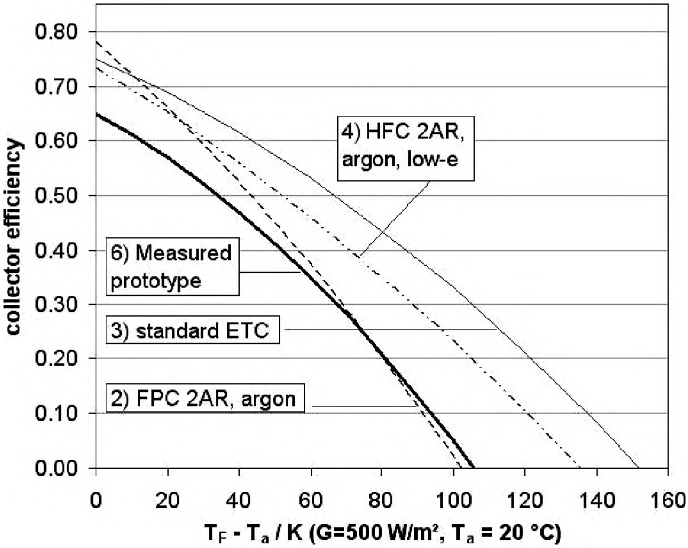


Fig. 4: Measured efficiency curve of first prototype of HFC, compared with three collectors from Fig. 2.

Further improvements, compared with our prototype, are feasible (for both the optical efficiency and the thermal losses) by optimizing the low-e coating, by enhancing the backside insulation, by using an argon filling for the glazing instead of air, and by optimizing the distances between the absorber and the lower glass pane and between the glass panes.

The focus of the measurements undertaken was to proof the principle of HFCs with regard to thermal performance. For this reason, the reliability and durability of HFCs (see e.g. the qualification test procedure of EN 12975) was not yet investigated. However, these issues are very important for the long-term success of a collector type and will be addressed in the future.

Conclusion and Outlook

For applications of solar thermal energy at temperatures above 80 °C or at low irradiance, the efficiency of the currently available flat-plate collectors is not sufficient. We suggest to raise the performance for operation at high values of ΔT/G by introducing glass covers with selective coatings into solar thermal technology.

In a double-glazed flat-plate collector, a low-e coating on the upper side of the lower glass pane is highly beneficial for reducing the heat losses through the glazing. According to our calculations, this so-called high-efficiency flat-plate collector (HFC) has the potential for performance values in the range of state-of-the-art evacuated-tube collectors.

The first prototype, that we built exclusively using commercially available components, achieved a conversion factor $\eta_0 = 0.648$, and a heat-loss coefficient $a_{60} = 2.5$ W/m²K. The achieved heat-loss coefficient is very promising and not far from the value aimed at (2.2 down to 1.8 W/m²K). The conversion factor of our collector is not yet competitive, but $\eta_0 \approx 0.70$ is achievable for HFCs without any R & D, just by using available components of high optical quality. The thermal performance can be further increased by using an optimized low-e coating, an enhanced backside insulation, an argon filling for the glazing instead of air, and by optimizing the thicknesses of the two gas layers within the aperture.

Low-e coatings for glazings need to be adapted for application in solar collectors. The coatings for windows and facades are optimized in a way that the thermal losses are minimized. Emissivities down to $\varepsilon \approx 0.03$ are common. This involves a considerable reduction of solar transmittance. For solar collectors, suitable coatings need to have a maximum solar transmittance, while higher emissivities than for windows are acceptable.
The reliability and durability of HFCs will be investigated thoroughly in our future work.

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Prospects for Large-Scale Solar Heating Systems in Europe

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Abstract

In total, there are about 19 million m² of solar collectors in Europe, corresponding to about 13 GWth (thermal power), where the majority of the collectors are installed in small systems with up to a few kWth. However, the relevant heat loads vary from a few kW up to several GWth and about 9% of the heating loads in Europe are covered by block and district heating systems. So far, only a minor part of the European collector market comprises large-scale applications. European large-scale solar heating plants having more than 500 m² (~350 kWth) of solar collectors have only about 125 MW thermal power altogether, i.e. about 1% of the installations. There is thus a need to develop large-scale applications in order to utilize the full potential of solar heat to cover existing heat loads.

The first large-scale solar heating applications were introduced in Sweden in the late 70's. Interests in large-scale solar heating, especially in Germany and Austria, increased during the 90's and about 80 plants with more than 500 m² of solar collectors are put into operation since mid 90's. Large-scale plants show more favorable costs of solar heat than most small systems and a strong market growth for small systems in Spain and France could now lead to an increased interest for large-scale applications also in Southern Europe. However, Sweden is still the leading country with more than 20 out of about 100 European large-scale plants (>500 m²; >350 kWth).

The European Solar Thermal Technology Platform (ESTTP) has been formed to develop a vision and a strategy for solar thermal in Europe. The majority of large-scale solar applications are installed in block and district heating systems and one of the ESTTP working groups will deal with the prospects for Solar District Heating (and Cool-

ing) Plants. The paper gives an update on the present status and describes initial visions and strategies to increase the development of large-scale solar thermal applications in co-operation with representatives for Euroheat and Power.

Introduction

There are about 19 million m² of glazed solar collectors in Europe with a total (design) power of 13 GWth. Solar collectors are mainly installed in small systems (2–30 m²) and so far only a minor part is related to large-scale applications. At present, there are about 100 documented plants having more than 500 m² (~350 kWth) of solar collectors. The total collector area of about 180 000 m² (~125 MW_{th}) in these plants corresponds to 1% of the total installations or about 40 000 SDHW systems.

Large-scale solar heating systems were introduced in the late 70's by the interest to develop solar heating systems with seasonal storage. Sweden had a leading role in the early demonstrations together with The Netherlands and Denmark. In the 90's the interest in large-scale solar heating increased in Germany and Austria and about 80 new plants with more than 500 m² of solar collectors have been put into operation since the mid 90's. Although there are a number of new plants installed, there is a negative trend with a decreased number of plants the last years (1).

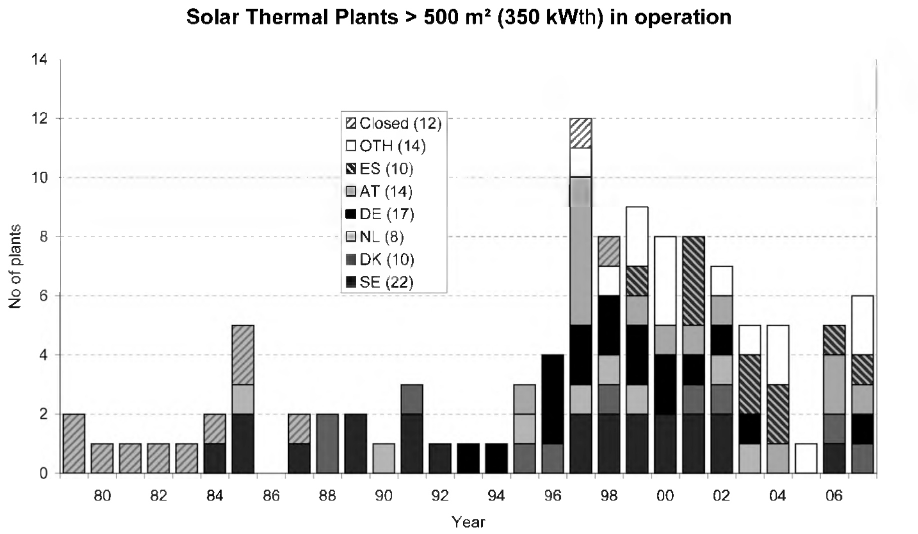

Fig. 1: No of solar heating plants related to year of commission

The number of plants related to year of commission is shown in Fig. 1 and the largest European solar heating plants (>2 MW_{th}) are listed in Table 1. At present there are about 100 plants with more than 500 m² of solar collectors in operation in Europe. Out of these 30 plants have a nominal design power of 1 MW_{th} or more. Sweden is still the leading country with a total of 22 plants, although eight Swedish plants, the first from 1979, have been closed after 10–20 years of operation and evaluation.

Plant, Year in operation	Owner, Country	Area [m²]	Size [MWth]
Marstal, 1996-	Marstal Fjernvarme, DK	18 300	12,8
Kungälv, 2000-	Kungälv Energi AB, SE	10 000	7,0
Breadstrup, 2007-	Braedstrup Varmevaerk, DK	8 000	5,6
Nykvarn, 1984-	Telge Energi AB, SE	7 500	5,2
Fernheizwerk/AEVG, 2006-	Solar Graz, AT	5 600	3,9
Falkenberg, 1989-	Falkenberg Energi AB, SE	5 500	3,8
Neckarsulm, 1997-	Stadtwerke Neckarsulm, DE	5 470	3,8
Crailsheim,	Stadtwerke Crailsheim, DE	5 470	3,8
Ulsted, 2006-	Ulsted Varmevaerk, DK	5 000	3,5
Ærøskøping, 1998-	Ærøskøping Fjernvarme, DK	4 900	3,4
Friedrichshafen, 1996-	Techn. Werke Friedrichsh., DE	4 050	2,8
Rise, 2001-	Rise Fjernvarme, DK	3 575	2,5
Ry, 1988-	Ry Fjernvarme A/S, DK	3 040	2,1
Hamburg, 1996-	Hamburger Gaswerke, DE	3 000	2,1
2MW, 2002-	ENECO Energy, NL	2 900	2,0
München, 2007-	Stadtwerke München, DE	2 900	2,0

Table 1: The largest European solar heating plants

The present developments include mainly large-scale plants with diurnal storage for residential heating, but also industries and heat driven cooling applications in Southern Europe. A continued interest to develop plants with seasonal storage remains mainly in Germany and Denmark (4).

Applications and Technologies

The majority of the plants supply heat to residential buildings. Typical operating temperatures range from low 30 °C to high 100 °C (water storage). Two thirds of these plants are connected to existing buildings, especially in Sweden, Denmark and Austria. About one fourth are built in connection to wood fuel fired heating plants: this is most common in Sweden and Austria. Non-residential plants are e.g. installed in industries and commercial buildings.

The majority of the plants are designed to cover the summer heat load – i.e. hot water and heat distribution losses – using diurnal water storages, but 18 plants are equipped with seasonal storages and cover a larger part of the load. The seasonal storages comprise water in insulated tanks (above or in ground) in 10 plants, the ground itself in 5, aquifers in 2 and a combination of ground and water in 1 plant. Nine plants are designed to cover the summer cooling load in heat driven cooling applications.

Most of the plants have roof-integrated or roof-mounted solar collectors while 18 plants in Sweden and Denmark have ground-mounted collector arrays. All except seven plants are equipped with flat plate collectors, mostly large-module collector designs. In a couple of cases in Sweden and Germany roof-mounted collectors are designed as more or less complete roof modules. Most plants have pressurised collector systems with an anti-freeze mixture; usually glycol and water, while four plants in the Netherlands have drain back collector systems.

District heating

The *Swedish* large-scale solar heating plants are used by district heating and housing companies, mainly for existing building areas, using both ground mounted collector arrays and roof-integrated or mounted collectors. The oldest plant still in operation dates from 1984. Kungälv Energi AB has recently built a 10 000 m² ground-mounted collector array as a complement to an existing wood-chips boiler plant. The plant yields close to 4 GWh/a out of a total load of about 100 GWh/a. Recent developments comprise decentralised solar systems connected to the primary district heating network in the city of Malmö.

Fig. 2: Solar district heating plant in Kungälv, Sweden.

The *Danish* large-scale solar heating plants are used in small district heating systems and all collectors are ground mounted. Based on Swedish experiences the first Danish plant, with 1 000 m² of ground-mounted collectors, was built in Saltum 1987. In 1995 Marstal District Heating decided to establish 8 064 m² solar collectors and a 2 100 m³ water storage tank to cover up to 15% of their heating load. The Marstal plant is now extended to 18 300 m² (12,8 MW_{th}) and is so far the largest solar heating plant in Europe. A recent study of the future potential for solar district heating has resulted in two new plants with 3,5 and 5,6 MW_{th}.

Block heating

The *Swedish* housing company EKSTA Bostads AB pioneered the use of roof-integrated solar collectors in new building areas already in the 80's. At present EKSTA owns and operates ~7 000 m² of roof-integrated collectors. Initially EKSTA used site-built collectors, but the latest development, a roof module collector mounted directly on the roof trusses, has now been applied in a couple of recent projects in new as well as on existing buildings. This development has resulted in even better integration in the building process, as well as further reduced investment cost and improved thermal performance.

The *German* large-scale solar heating plants are mainly applied in new residential building areas using roof-integrated or mounted collectors. Until 2003 eight projects with seasonal storage and about 50 large- to medium-scale projects with short-term storage had been realised and there is an ongoing R&D programme until 2008. There are two plants with >5 000 m² of roof-integrated collectors and a new plant with 2 900 m² is under construction in Munich (4).

The first large-scale solar plant in *Austria* – a local biomass-fired heating plant complemented with a solar system – was built in Deutsch-Tschantschendorf in 1995. The experiences from this plant were promising and more than 10 large-scale plants are in operation. Graz is the large-scale solar city of Austria with three plants, the largest one with >5 000 m² connected to the primary district heating network.

The most widely implemented application of large solar heating systems in *The Netherlands* is collective housing, institutions and homes for the elderly. Most systems have about 100 m² of solar collectors, but some are larger, for example "Brandaris" in Amsterdam. Two large-scale plants are designed with seasonal storage, one is a recent plant with 2 900 m² of solar collectors connected to an aquifer storage. There are further a couple of solar block heating plants in *France*, *Switzerland* and *Finland*.

Other applications

A couple of the large solar systems in the Netherlands and *Greece* are industrial heat applications, e.g. a plant with 2 400 m² of flat plate collectors on the Van Melle industry in Breda. The first large-scale solar cooling plant – 2 700 m² of flat plate collectors providing heat to two adsorption chillers (2 x 350 kW) – was installed in Athens, Greece in 1998. At present there are a couple of large-scale solar cooling plants in *Italy* and *Spain*, e.g. a plant with 1 500 m² of high temperature collectors for industry cooling by Inditex in Spain.

Vision and strategy

The European Solar Thermal Technology Platform (ESTTP) has been formed to develop a vision and a strategy for solar thermal in Europe. One of the working groups will deal with the prospects for Solar District Heating (and Cooling) Plants. The work is planned in co-operation with representatives for Euroheat and Power and important background documents are the WP 1 and WP 4 reports developed within the Ecoheatcool project (2,3).

Table 2 shows a first estimate of the potential for large-scale solar heating based on the goals for installed solar thermal capacity in the recent ESTIF report "Solar Thermal Action Plan for Europe – Heating and Cooling from the Sun" (January 2007). The simple assumption here is that we will have the same relation between (large) solar block and district heating systems and other (small) solar heating systems in the next decades as we have right now (about 1:100). The potential for solar block and district heat is thus estimated to provide 2,0–6,8 PJ in 2020 (about equal to the total solar heat in 1990).

Year	Capacity [GWth]	Heat [PJ]
1990	0,022	0,045
2005	0,11	0,24
2020 Minimum - Ambitious	0,91 – 3,2	2,0 – 6,8
Long term	12	26

Table 2: First estimations of solar block and district heat in Europe

The total net heat demand in "Europe" is estimated to about 21 700 PJ (about 6 030 TWh) out of which about 2 000 PJ (about 555 TWh) is covered by district heat (2). The minimum goal for 2020, about 2 PJ solar heat (Table 2), is of the same order as the potential for solar district heat presented in the Ecoheatcool project (3). However, assuming that the district heating sector will keep their positions from now to 2020, the estimations in Table 2 above show that solar (block and) district heat could cover between 0,1 and 0,4% of the heat sold in the European district heating sector in 2020 (2,0–6,8 in relation to 2 000 PJ) and slightly above 1% in the long term (26 in relation to 2 000 PJ), which are far too pessimistic numbers.

The working group will develop a more comprehensive vision based on identified barriers and possible progressive and conservative policy scenarios, as well as foreseen technology developments. A vision based on a "conservative policy scenario" will probably be close to the vision according to the simple approach above, while a vision based on a "progressive policy scenario" should show a much larger potential.

Besides promoting more progressive policies, the major challenge is to combat major non technical barriers, e.g. low alternative heat price (heat from combined heat and power and waste incineration during the summer period, cheap heat from coal fired plants in East Europe), competition with decentralized heating and cooling, including natural gas networks, lack of information, knowledge and experience from block and district heating (and cooling) systems in many regions (South Europe), lack of information and knowledge about solar block and district heating systems among district heating actors, lack of knowledge dissemination, as well as lack of contractors able to build well designed large-scale solar systems.

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Experiences with the German Market Stimulation Programme

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Introduction

By providing investment grants, the German Market Stimulation Programme, or Marktanreizprogramm (MAP), has created Europe's largest market for solar thermal collectors. With investment grants totalling € 572 million, 523,602 solar thermal installations were supported by the end of 2006. However, because the MAP budget is fixed annually, it is a recurring challenge to stimulate constant market growth without exceeding budget restrictions. This paper describes the evolution of the MAP as well as its achievements. A discussion on how best to manage such large incentive programmes is included.

Evolution of stipulations

The German MAP came into force on September 1st, 1999. When the program began, an annual budget of € 100 million was allocated for different types of renewable energy technologies. The level of support and the framing conditions have been constantly adapted over the life-time of the programme (Table 1). In 2007, an annual budget of € 214 million for all technologies including biomass furnaces and deep geothermal installations is available. The funding for the MAP originates from the revenues of Germany's Eco-tax[1]. Although it was not designed exclusively for solar thermal, most of the funding available through this program has been allocated in support of solar thermal installations. Individuals, small and medium-sized enterprises, municipalities, and other registered associations are eligible to apply for grants and soft-loans through the MAP. Grants are provided on a € per collector area (m^2) basis.

Throughout its lifetime grant levels of the MAP have been altered. These adjustments were made primarily in an attempt to compensate for insufficient annual budgets, or to allow for higher grants and therefore stronger support for market growth. However, since 2003, grants have been decreased incrementally in terms of €/m^2 of solar thermal collector area. Decision-makers, in-so-doing, assumed that the support available under a successful incentive should be continuously reduced to reflect the development of the technology of focus, simultaneously meeting the requirements of European

State Aid regulations. Additionally, to simplify the administrative process the distinction between flat-plate and vacuum collectors was abandoned in 2001. This consolidation of definition put vacuum collectors at a disadvantage in terms of the share of the grant per total investment.

Coming into force	Investment Grant (€/m^2)		Remarks
	Domestic hot water only	Space heating Combination	
01-09-1999	Flatplate: 128 €/m^2 Vacuum: 167 €/m^2		Minimum yield: 350 kWh/m^2 yr; Expansion of existing plants: 50 €/m^2
25-07-2001	87 €/m^2		Minimum yield: 350 kWh/m^2 yr; no expansions
23-03-2002	92 €/m^2		
01-02-2003	125 €/m^2		
01-01-2004	110 €/m^2		Minimum yield: 525 kWh/m^2 yr; Expansion of existing plants: 60 €/m^2
01-07-2005	105 €/m^2	135 €/m^2	
21-03-2006	84 €/m^2	108 €/m^2	Minimum yield: 525 kWh/m^2 yr; Expansion of existing plants: 48 €/m^2
21-06-2006	54.60 €/m^2	70.20 €/m^2	
12-01-2007	40 €/m^2 Minimum 275 €	70 €/m^2	Minimum yield: 525 kWh/m^2 yr; Expansion of existing plants: 30 €/m^2

Table 1: The development of grant allocations for solar thermal collectors within the German MAP

Performance requirements (minimum annual energy yields of 525 kWh/m^2) were introduced to ensure minimum technical standards, thereby excluding low performing solar thermal collectors. These requirements excluded unglazed and plastic absorber collectors typically used for swimming pool heating. The performance requirements were increased in 2004 to fulfil European Union State Aid regulations.

In 2005, a distinction was introduced in the MAP between solar thermal collectors which solely provide domestic water heating and those which also provide space heating. The bulk of solar thermal investments were granted single family houses. In the design of the MAP, single family residences were deemed easier to target than multiple-apartment buildings. In their investment decisions, owners of multiple-apartment buildings tend to require that the cost gap with fossil fuels is completely covered. As a result, more support is required per square meter of collector area for these larger systems albeit the heat generation costs are comparatively lower than those of smaller systems. As such, it was decided that the solar thermal market, in terms of collector area, could be increased by shifting the demand within the single residence sector from small domestic water heaters to larger, combination installations which include space heating.

Achievements with solar thermal collector systems

The number of solar thermal installations supported by the German MAP increased from 26,000 in the year 2000 to more than 102,000 in 2006 (Fig. 1). It follows that the total solar thermal collector area supported increased from nearly 200,000 m² in 2000 to 978,000 m² in 2006. If MAP budget restrictions had not precluded the allocation of additional grants to applicants, the annual installation in 2006 could have been even higher.

The annual budget available for solar thermal installation grants has fluctuated between € 40 million and € 110 million. In 2006, € 94 million was provided. At the same time, the average level of support granted per installation decreased from € 1588 (16.1 % share of average investment costs) in 2000 to € 917 (12.6% share of average investment costs) in 2006. Most grants went to the installation of flat-plate collectors. Vacuum tube collectors have accounted for only 12 % of the total supported area.

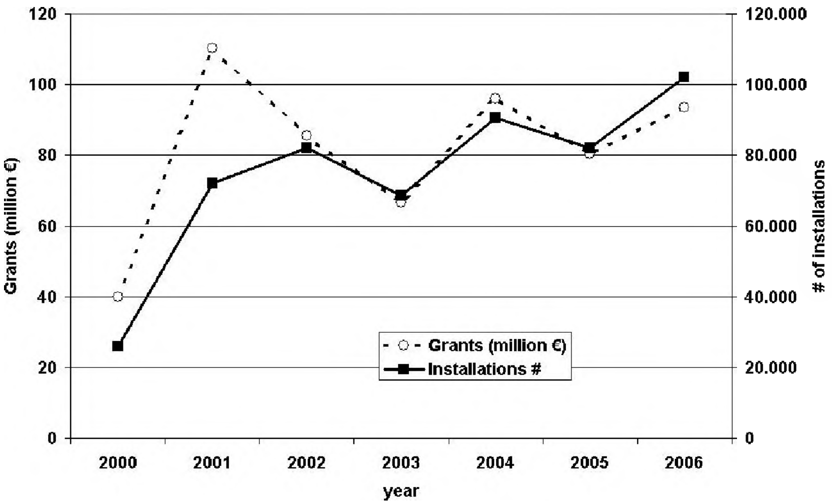

Fig. 1: A comparison of the number of installations supported by the MAP annually and the coinciding sum of grants allocated by the MAP. (BAFA 2007).

The grants provided by the MAP are not sufficient to cover the entire cost gap between solar thermal collectors and conventional boilers using fossil fuels (Fig. 2). Motivated solar thermal investors shoulder a cost burden higher than they might otherwise. Nonetheless, MAP grants have been an important driver to motivate potential investors. In a survey of solar thermal investors supported by MAP financing, three quarters said that they would have not invested at all or would have invested differently had the grant been unavailable (Langniß et al 2004). To potential investors, the availability of the

MAP grant confirms the creditability and the value of solar thermal systems. Thus, it is often used as a marketing tool.

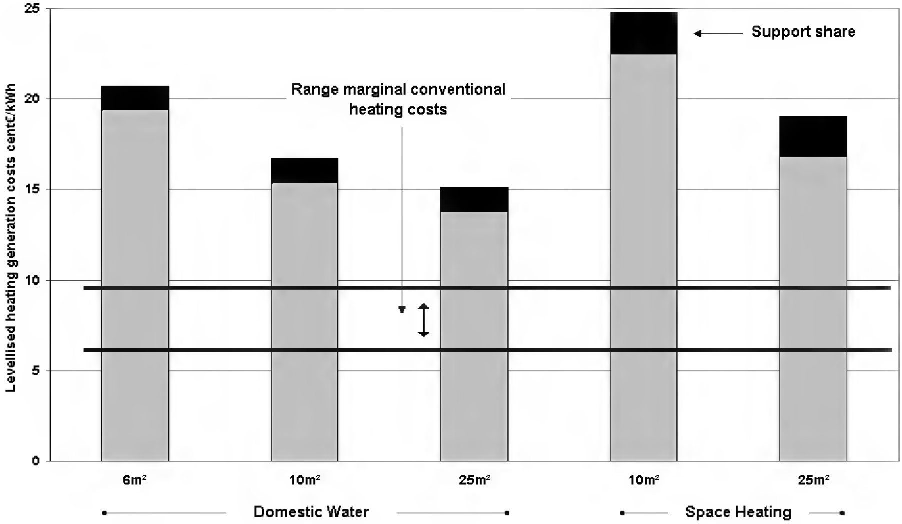

Fig. 2: Levellized heat generation costs of solar collector systems installed in 2005 compared by application and collector area (derived from Langniß et al 2006).

The correlation between the number of MAP applications and the available grant levels clearly demonstrates the importance of the MAP for market deployment (Fig. 3). In February 2003, the increase from 92 €/m² to 125 €/m² of grant available led to a threefold increase in the number of grant applications. The number of applications increased further in the autumn of 2003 after a decrease in grant levels was indicated to take place by February 2004. When grants were decreased to 110 €/m², the number of applications dropped by 60%. Of course, some of the extremity of the precursory increase and the sequential drop in application number may be explained by the decision of investors to advance in their investment such that they may benefit from the higher grants. When grants were increased for solar powered space heating installations (and an accompanying decrease, however slight, for solar panels purely for domestic water heating) in the summer of 2005, the number of grant applications again increased immediately. Due to this favourable grant for solar space heating installations, their share of the total installed collector area increased from 41% to 62%.

In 2006 and 2007 other market drivers have taken precedence over the MAP for the development of solar thermal in Germany. Increasing prices of conventional heating oil, problems with the natural gas supply and the public debate on climate change have been powerful catalysts for a shift away from fossil fuels in favour for solar thermal systems and other renewable energy sources. The strong demand for solar thermal collectors and for grant support has put a great deal of stress on the available budget. Consequently, grants were substantially decreased twice in 2006 before the programme was entirely exhausted for the year in August 2006. Despite the insufficient budget, record levels of annual installations were set in 2006 in Germany with 1.5 million m² installed against 1 million m² in 2005 (BSW 2007).

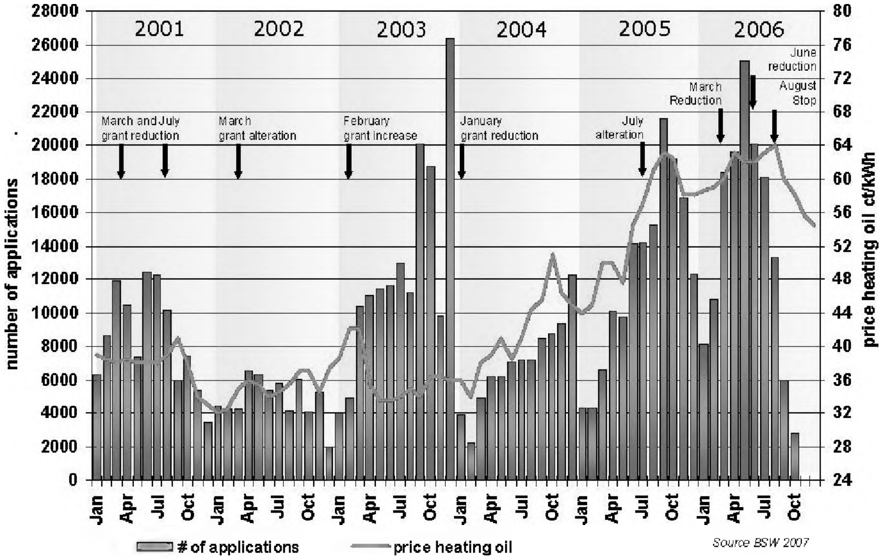

Fig. 3: Fluctuation in the number of MAP grant applications as compared to the development of conventional heating oil prices (BSW 2007).

The autonomous demand for small solar collector systems allows for more accentuated support to be provided for larger solar systems. The vast potential for more sizable solar systems is largely untapped. Such systems provide heat at lower costs than small systems simply due to economies of scale. However, as mentioned above, higher levels of support are required as larger systems are typically purchased by commercial entities rather than private households. As such, requirements on economic feasibility are higher. As a result, beginning in 2007 installations with an area of 20 m² to 40 m² supplying space heat to houses with at least three apartments will receive a grant of 210 €/m². Installations larger than 40 m² are eligible to receive a grant worth 30% of the total investment.

Conclusions

Although an average of only 15% of solar thermal investment costs have been provided, the grants available through the German Market Stimulation Program (MAP) have been the most important driver in creating Europe's largest solar thermal collector market. The MAP has been successful in stimulating the market for solar thermal heat by financing a significant number of solar thermal installations since its initiation in 1999. However, despite this success the MAP has been harshly criticized for the nearly annual fluctuation in available funding. This caused insecurity in the reliability of the fund as was reflected in a fluctuation in application and annual development rates. The inability of the German MAP to assure financing to all applicants may therefore have restricted the growth of the solar thermal market as well as investments in manufacturing facilities to a certain extent.

The MAP provides an example of the inflexibility of annual public budgets in the short term. It remains a constant challenge to adapt grant levels and stipulations to quickly changing market demands and framework conditions like fluctuating oil prices and the public perception of climate change. For further, constant growth of the solar thermal market the support of the MAP must be made independent of shifting and restricted public budgets.

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[1] The German Ecotax was also implemented in 1999. This legislation placed a tax on conventional fuels for transport and electricity generation. A portion of the revenue from the Ecotax is used to supply MAP funding.

Creating a credit market for solar thermal: the PROSOL project in Tunisia

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INTRODUCTION AND BACKGROUND

The United Nations Environment Programme (UNEP) has been working with the finance sector since the late 1990s to develop innovative mechanisms for the promotion of sustainable energy technologies in developing countries. Through its Renewable Energy and Finance Unit, UNEP has implemented a variety of "financial catalysts" with the aim to lower risks, buy down transaction costs, build capacity and address soft market barriers that constrain sustainable energy technologies growth.

The MEDREP Finance initiative represents one of the most recent and successful examples. It has been developed within a manifold programme launched by the Italian Ministry for the Environment, Land and Sea at the World Summit on Sustainable Development of Johannesburg in 2002. The aim of the Mediterranean Renewable Energy Programme (MEDREP) is to expand the share of renewable energy technologies in the Southern Mediterranean region, in order to reduce poverty, combat climate change and achieve long-term sustainability objectives.

A series of projects are being developed in Tunisia, Morocco and Egypt. Below, the structure of the PROSOL project in Tunisia is reported, as well as the results achieved. First, an overview of country-specific conditions is provided.

FRAMEWORK CONDITIONS AND SOLAR THERMAL POTENTIAL IN TUNISIA

Tunisia has a significant solar potential, with very high irradiation rates. According to the GIS-based data made available by the European Commission's DG Joint Research Centre (JRC, 2007), the country benefits from 1,700 to 2,200 kWh/m^2 per year. The National Agency for Energy Conservation (ANME) estimates that solar thermal panels could satisfy approximately 70–80% of sanitary hot water needs in the residential sector. So far, solar water heaters cover only 3% of the market in the domestic sector. As one can see, the market is dominated by LPG-fired boilers, which constitute 78% of the existing stock (Missaoui and Amous, 2003).

While sun is an abundant source in Tunisia, the country has scant fossil fuel reserves and its net energy balance has been showing negative values since 2001. In particular, LPG is entirely imported.

Water heater typology	% of stock
Electric	10.40%
Natural gas	8.00%
LPG	78.40%
Solar thermal	3.20%

According to the data provided by the International Energy Agency (IEA, 2007) in 2004 LPG imports reached 364 ktoe (+22% over 2000 and +164% over 1990). Hot water demand is over 30 million m³ per year, and is projected to increase up to 70 millions m³ by 2010. This would imply a further growth in LPG imports, if current energy consumption patterns remain the same. This would translate into a higher deficit in the balance of payments, and in an increase of government's expenditures to subsidize the product. Currently, LPG is subsidized in a measure corresponding to 50% of its real price.

Solar thermal has been repeatedly proposed as a solution to lower the country dependency from imported fossil fuel sources. The first solar thermal energy strategy was developed by the Tunisian government in the 1980s. But only in the period 1997–2001 a real market and technology infrastructure have been developed, thanks to a project financed by the Global Environment Facility (GEF) and the Belgian Cooperation. The support mechanism was based on a 35% capital cost subsidy. At the end of the period, 50,000 m² of new solar thermal panels were installed, 8 suppliers (among which 3 manufacturers) and over 130 installers were operating in the market, for a total of 260 new jobs created. Despite these important results, as soon as project funds expired solar water heater sales dropped again.

The PROSOL project

PROSOL (Programme Solaire) is a 2-year project developed within the MEDREP umbrella. It has a total budget of Euro 1.7 millions, donated by the Italian Ministry for the Environment, Land and Sea.

The project was initiated in 2005 by the Tunisian Minister for Industry, Energy and Small and Medium Enterprises and the National Agency for Energy Conservation (ANME), with the support of the UNEP-MEDREP Finance Initiative.

The objective of PROSOL was to revitalize the declining Tunisian solar water heater market. The innovative component of PROSOL lies in its ability to actively involve the finance sector, and turn it into a key actor for the promotion of clean energy and sustainable development. By identifying new lending opportunities, banks have started building dedicated loan portfolios, thus helping to shift from a cash-based to a credit-based market.

The main features of the PROSOL financing scheme are:

- A loan mechanism for domestic customers to purchase solar water heaters
- A capital cost subsidy provided by the Tunisian government, up to 100 dinars (57 euros) per m^2
- Discounted interest rates on the loans, progressively phased out.

A series of accompanying measures have been developed, which include an awareness raising campaign, a capacity building programme and carbon finance.
Besides UNEP and ANME, key partners include:

- The Société Tunisienne de Banque (STB)
- Two commercial banks (UBCI and Amen bank)
- The State electricity utility STEG (Société Tunisienne d'Electricité et du Gaz)
- Manufacturers, importers and installers of solar water heaters
- Local consultants

Functioning of the financing mechanism

In the PROSOL scheme, loans for solar water heaters are effectively driven by suppliers, who act as indirect lenders of money for their customers. The process begins when a customer decides to purchase a solar water heater from an eligible supplier. It is worth highlighting that only suppliers accredited by ANME can operate within PROSOL. To this end, products must meet a series of technical requirements and performance standards, as set in a manual prepared by ANME.

The supplier submits a loan application to a participating Tunisian bank that qualifies the customer's ability to repay the loan. Once the bank approves the loan to the supplier, the solar water heater is installed at the customer's home. The customer pays only the administrative costs of the process.

After the installation, the supplier receives:

- The subsidy payment from ANME of 200 dinars (€ 114) for a 200-litre system or 400 dinars (€ 228) for a 300-litre unit, and
- A payment from the bank of 750 dinars (€ 428) for the 200-litre solar water heater, or 950 dinars (€ 542) for the 300-litre system.

The customer repays the loan on a pro-rata basis over a five-year term, through the electricity bills issued bi-monthly by STEG. In some cases, however, the extra cost for the solar water heater is compensated by reduced electricity consumption, thus lowering the overall amount to be paid.

Within this scheme, banks do not have any direct contact with the customer, who is the final beneficiary of the loan. They deal instead with solar water heater suppliers. This unusual arrangement provides a double security: loans are officially granted to the solar water heater suppliers who are responsible for repayments, and the consumer cannot easily default because the loan debt is recovered through the customer's electricity bill. In the event a customer does not pay the bill (and hence the solar water heater loan), banks can take action against the solar water heater suppliers that were granted the loan. At the same time, STEG suspends the electricity supply to the customer.

Highlights of main features

The most distinctive aspects of the PROSOL financing scheme are: the engagement of banks and the active involvement of the State utility.

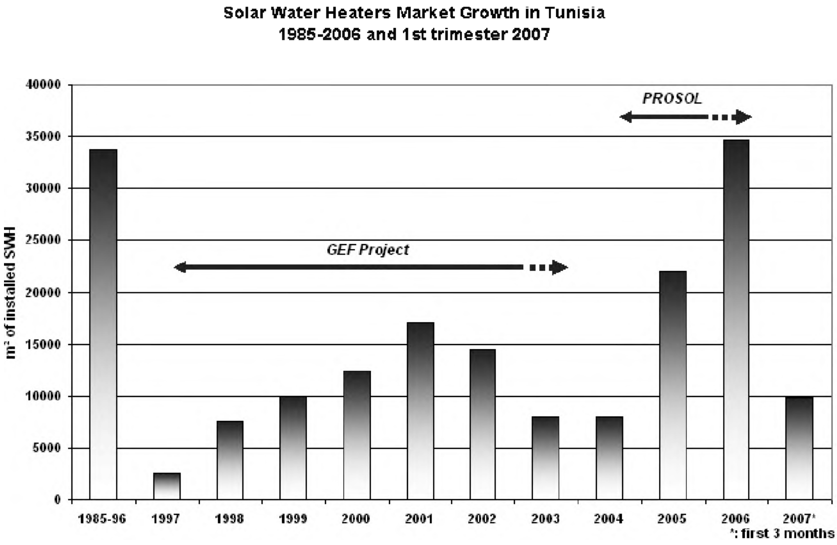
In PROSOL, banks play a very important role since they provide the necessary funds to develop the market, accounting for the highest percentage of the finance for solar water heaters.

The engagement of STEG in recovering the loan payments through its electricity bills has provided enough guarantees to banks to extend the loan terms and lower the interest rates. In PROSOL, loan duration was five years instead of the usual three-year term. As for interest rates, the commercial lending rate for similar loan products in Tunisia is 14%. Within PROSOL, banks have agreed to a 7% reduction. Through the MEDREP Fund, UNEP has provided a 7% interest buy-down for loans disbursed in the first 12 month and 3% for subsequent loans. This means the rate initially charged to customers was 0% and after 12 months 4%.

The transparency of the system is ensured by independent third party evaluation. At the beginning of 2007, PROSOL was audited by KPMG.

Results and Outlook

Launched in April 2005, the PROSOL project has resulted in an immediate success. In less than one year (April-December 2005), sales reached the record figure of 7,400 solar water heating systems, for a total surface installed of 23,000 m². At the end of 2006, an additional 11,000 units were sold, corresponding to approximately 34,000 m². The capacity added in the year 2006 was higher than the cumulative capacity installed in the entire period 1985–1996, prior to the GEF project. On an annual basis, the 2006 figure doubled the sales in the previous best year – 2001 (under the GEF programme). Overall, in less than two years the solar water heater market has surpassed 57,000 m², representing as much as 50% of the cumulative surface installed from 1985 to 2004. The figures for the first trimester of 2007 (after the end of PROSOL) confirm this encouraging trend.



As regards geographical distribution, the majority of solar heating systems are concentrated in the Northern part of the country and in coastal areas.

In terms of equipments, most installations are represented by flat plate solar panels but vacuum tube collectors are slightly gaining market share.

As for financial data, banks have granted loans for more than 6 million dinars (€ 3.4 million) in 2005 and 9 million dinars (€ 5.3 million) in 2006.

The number of solar water heater suppliers eligible within PROSOL has rapidly increased, passing from 5 to 9 in few months and stimulating other applications. Today, the number of companies selling solar water heaters is 14, of which 4 producers. A new manufacturing plant is being established and new technology providers are entering the market.

As far as installers are concerned, their number has reached 384 units, i.e. three times the figure achieved at the end of the GEF project.

These remarkable results have led the Tunisian government to set very ambitious targets. The 11th quinquennial plan has fixed the objective to install 540,000 m² in the period 2007–2011, i.e. over 100,000 m² per year on average. If this target is met, the annual market for solar water heaters in Tunisia would become comparable to current levels of countries like Spain or Italy, whose population is 4–6 times higher. Solar thermal capacity in operation would reach 48 kWth per 1000 inhabitants, which is comparable to current levels of countries like Germany, Denmark or Switzerland (ESTIF, 2006).

Capacity installed and main economic and environmental benefits over the life cycle of the SWH (15 yrs)	1996-2004 Around the GEF period	2005-2006 PROSOL-related	2007-2011 New target
Solar thermal capacity installed (kW_{th})	57,000	40,000	378,000
Avoided LPG subsidies (TND)	28,219,000	19,665,000	186,300,000
Primary energy savings (toe)	56,000	39,000	373,000
Cumulative CO_2 emissions avoided (tonnes)	307,000	214,000	2,025,000

Moreover, PROSOL has led to an important policy change. In fact, the Tunisian government has made solar water heaters eligible for the energy subsidy that previously was provided only on LPG.

In spite of the considerable strengths of the project, there were also some drawbacks. Two issues need to be addressed:

- The level of exposure of solar water heater suppliers, and
- The lack of dedicated tools for maintenance

As far as the former is concerned, in PROSOL solar water heater suppliers were the sole party dealing with banks and were obliged to accept responsibility for the loans they had taken out on behalf of their customers. Ironically, a successful vendor was measured by his level of indebtedness. This limit has been corrected in the new "PROSOL2", which was launched earlier this year. In "PROSOL2", end users are directly granted the loan from the bank, thus eliminating the burden for suppliers. The new mechanism has been entirely developed by local actors, and neither UNEP nor other international institutions are involved. This represents a very positive outcome, since it demonstrates that a self-sustaining market and policy decision making process are being built up.

With respect to the second issue, an audit of half the collective solar thermal surface installed during the GEF project led in early 2007 showed that over one third of the sample was not working anymore because of lack of maintenance. Although within PROSOL specific guarantee requirements are asked to vendors, similar problems might occur if no dedicated measures are adopted.

To avoid malfunctioning in the future, a maintenance cost subsidy has been incorporated in the new Solar Water Heating Loan Facility for the Tourism and Service Sector, in order to ensure long term efficiency of the systems installed, and create expertise in the sector. After the signing of the agreement by the Italian Ministry for the Environment, Land and Sea, the National Agency for Energy Conservation and UNEP the new facility is just being launched.

Accompanying measures

In order to give visibility to the project, inform customers on the advantages of the mechanism and promote the purchase of solar water heaters, a comprehensive communication plan was developed at national level. The following media were used: TV, radio, posters, brochures.

Moreover, a Training Support Facility was established to build capacity amongst financiers and expand their confidence degree in renewable energy technologies, with the ultimate goal to increase the number of sustainable energy loan portfolios.

Finally, carbon finance is another important component of PROSOL. A Project Idea Note (PIN) was prepared by ANME and submitted to the Designated National Authority in April 2006. A Project Design Document (PDD) is currently under development.

Conclusion

The PROSOL project is proving to be a real success story. In only two years, it has helped achieve a series of long-term goals which go far beyond the actual number of solar water heaters installed.

The first important change driven by the project is the setting by law (Law 82/2005 and decree 2234/2005) of a 20% capital cost subsidy on all new solar water heating installations. This provides a further stimulus to the development of the renewable energy technology market.

In order to improve technology level and decrease costs, the decree 4/2006 has exempted solar water heaters from VAT and decreased custom duties.

These measures help create a more level playing field where solar thermal can better compete against conventional energy sources, like natural gas or LPG.

The capacity building and the information exchange have also played an important role in stimulating a dynamic attitude of the Tunisian government, which has set very ambitious targets for solar thermal and has established a comprehensive strategy made of policy, financial and fiscal incentives, awareness raising campaigns (including the "Solar month" campaign), monitoring measures, etc. Engaging the banks has proven to be a successful strategy, since they leveraged enough financial resources to stimulate the creation of a market for solar thermal. As other UNEP projects, PROSOL was relatively small-scale, but has triggered rapid expansion of the solar water heater market. This proves that considerable results can be achieved even with a limited budget, if money is channelled in the proper direction and synergies are exploited. With this respect, an extensive stakeholder consultation process has been carried out and collaboration with all partners involved has been tied in.

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A Bonus Model as a new concept to support market penetration of Solar Thermal Appliances

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Introduction

A lack of appropriate legislation at the EU and Member State level for the support of renewable heat generation (RES-H), including for solar thermal, is one of the main barriers for the EU to reach its overall 10% RES target set forth in the 1997 White Paper on Renewable Energy. In most Member States support mechanisms tend to be small-scale and relatively unsophisticated in the incentives they offer to industry stakeholders and consumers. In addition often support instruments, e.g. investment support or soft loans, are based on public budgets thus conflicting with stable support conditions as this might lead to stop-and-go market developments, which in turn undercut development of competitive renewable industries. In countries in which requirements or incentives for the use of renewable heating devices, especially solar thermal appliances have been included in national building standards, the effect is often limited to new buildings neglecting the huge potentials in the building stock.

The Bonus Model concept, subject to this article, seems to be a suitable instrument to create favourable investment conditions for RES-H technologies as well as to overcome budget dependant barriers linked to current support frameworks. The Bonus Model concept has been developed in the scope of a comprehensive scientific analysis commissioned by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety specifically addressing enhanced RES-H market penetration in Germany (5).

Extension Targets for RES-H in Germany

In 2006 renewable energy sources contributed 5,9% to the total heat generation in Germany. The starting point of our study was the assumption that the share of RES-H has to increase from the present level to 7,8% in 2010, and to 12,3% in 2020 (Fig. 1). In the long term the share has to be further expanded to approx. 35% in order to allow Germany to reach a 80% CO_2 emissions reduction target by the middle of this century (compared to the Kyoto base year 1990). We further assumed that the share of RES-H distributed through local district heating networks has to gradually increase to approx. 65% in 2050. This is mainly due to the following reasons:

- Solar Thermal: Compared to individual systems the integration of solar collectors into a local district heating network including large storage systems allows for cheaper heat storage as well as for longer storage periods.
- Biomass: Large biomass plants are not restricted to the input of high quality wood pellets but allow for the use of cheaper biomass sources which requires higher investments in flue gas cleaning (which is economically not viable for individual systems).
- Geothermal: Due to high costs for exploiting geothermal reservoirs in large depths this technology is only economically viable if a larger number of consumers are integrated into one supply system connected by a local district heating network.

In addition to improving support for RES-H market penetration the key prerequisite for achieving the ambitious targets lies in efficiency measures especially in the building sector. Here the existing policy framework has to be further developed to allow the building sector to exploit the energy saving potentials which are primarily existing in the building stock.

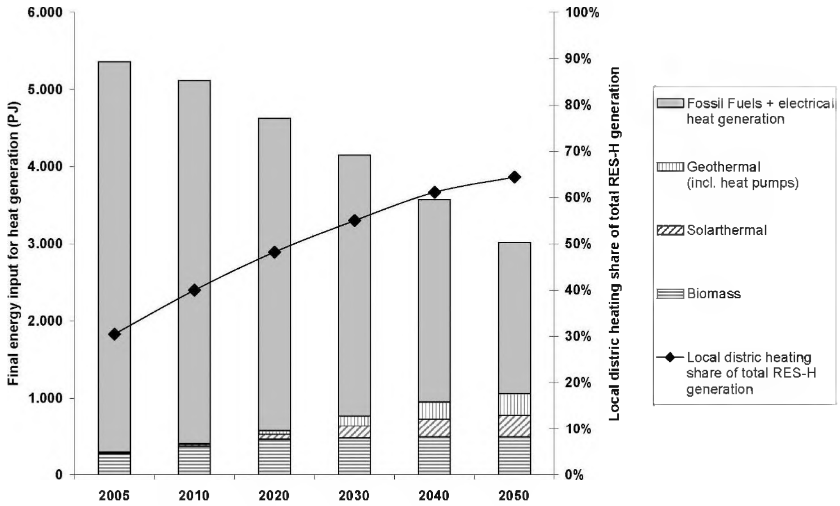

Fig. 1: Scenario for the development of RES-H until 2050

The need for additional instruments

In Germany the discussion about the need for additional support for renewable heat is mainly driven by the insight that all existing instruments did not effect an expansion of RES-H production to the extent necessary. At present market penetration of renewable heat devices is mainly supported through the Market Incentive Program (Marktanreizprogramm MAP) which is following a subsidy and soft loan concept. Although this program can be regarded as one of the most successful policy approaches to stimulate RES-H market penetration throughout Europe (which is mainly due to the financial volume of the program providing several million Euros per year) the MAP has some considerable shortfalls. The main shortfall concerns the investment security provided by the program which is mainly due to its dependency on the public budget. Program interruptions, ongoing political discussions about the program's volume and regular amendments of the specific supporting conditions stand in contradiction to the need for stable long-term support conditions.

What are the main pre-conditions which policy makers should take into account when implementing new instruments to support RES-H: As already outlined above the key element of successful support is the reliability and stability of the support framework (e.g. expressed by the investment security provided by different policies). Furthermore the architecture of public support should be designed in a way as to allow achieving the extension targets at the lowest possible cost. This also includes the transaction costs of the system which incur at authorities and all other stakeholders involved. Potential windfall profits which can occur in the case of those renewable energy systems that would be installed even without external support (e.g. through subsidies) should also be avoided to the extent possible. Finally policy makers are advised to carefully consider the issue of acceptance at the side of the various stakeholders involved.

The Bonus Model Concept

The general concept

The Bonus Model is a rather new concept in the discussion about suitable support options for RES-H. The Bonus Model can be characterised as purchase/remuneration obligation with fixed reimbursement rates. The model involves major mechanisms of a classic feed-in scheme which is well known from the RES-E sector. Operators of RES-H devices (including solar thermal appliances) are entitled to receive a fixed bonus payment per kilowatt hour of heat produced. The bonus level is set by the government and established by law. The bonus level can be easily adapted and periodically adjusted to the specific needs of the various RES-H technologies and the system can provide good incentives for the implementation of grid based heating systems. The bonus is paid by those companies which fall under the German Energy Tax Act and handle fuels for heating purposes (Fig. 2).

Organisation of support

The interaction between those who operate renewable installations eligible to receive a bonus (beneficiaries) and those which are obliged to pay the boni (obliged parties) requires special attention. The relationship between the two parties in the heating sector differs significantly from the corresponding relationship in the electricity sector under the scope of the Renewable Energy Sources Act (EEG), a feed-in tariff system for renewable electricity. Under the EEG electricity is physically fed into a network which allows for the distribution of a physical good. In the heating sector the situation is different. Heat is mainly produced in individual-house systems and a homogeneous and country-wide transmission and distribution network is missing. So what is the equivalent which obliged companies receive in turn to their bonus payments? One option is to introduce a surrogate in the form of certificates of value for renewable energy, representing the environmental benefit associated with the production of RES-H. In this case the beneficiaries may provide certificates of value, not (heat) energy itself, to the obliged parties. Another option is to dispense entirely with any sort of tangible service in return: the remuneration is then the direct equivalent, in legal terms, of the environmental recovery brought about by the third parties (i.e. the producers of RES-H).

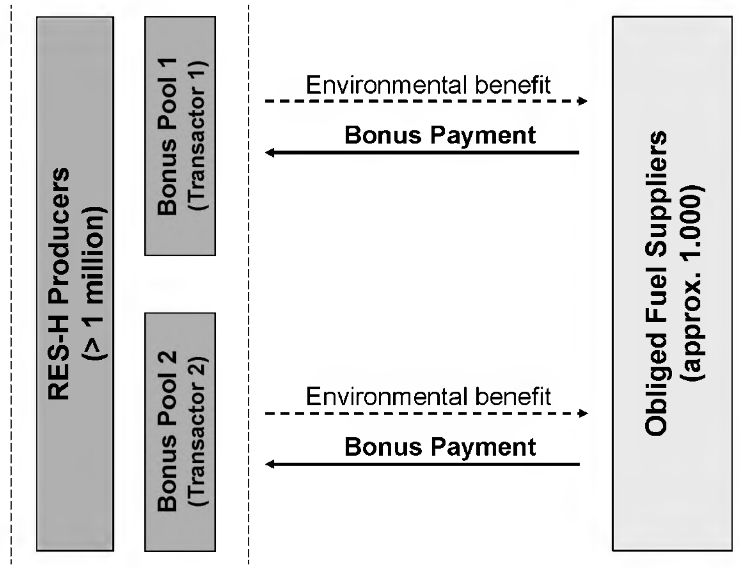

Fig. 2: Overview of the principle architecture of the Bonus Model

One of the key design elements is the organisation of the relationship between the beneficiaries and the obliged parties. Here legal aspects have to be carefully taken into account. An instrument design needs to be chosen which especially removes the risk that the model is legally classified as special levy. For instance if the funding flows between the beneficiaries and the obliged companies are managed by the state, or agencies commissioned by it, outside the general public budgets, this means that in German constitutional law, the instrument concerned must be classified as a special levy. However special levies underlie stringent conditions: They may only be collected from a homogeneous group which bears group responsibility for the legal objective set, and the revenue collected must be used for the benefit of the whole group. This latter condition in particular proved to be an (excessively) difficult obstacle in the case of the Bonus Model. Therefore, in order to avoid legal problems the state must not take a role in the processing and especially the administration of the financial flows.

Under the Bonus Model in principle each household operating a solar collector would be entitled to apply for funding. This would involve millions of beneficiaries leading to millions of transactions. Therefore in our proposed instrument design we have introduced a key position which is taken by pooling organisations (called "transactors"). The role of transactors is to aggregate the interests and bonus claims of the beneficiaries thus acting on their behalf. All beneficiaries are obliged to join at least one transactor in order to be entitled to receive the bonus.

In order to minimise the administrative burden especially for small beneficiaries (households) which constitute the majority of all eligible RES-H operators the routines applied within the Bonus Model should be simplified where possible. Preferably small beneficiaries will scarcely notice that there has been a change in the funding framework (by replacing the MAP through a Bonus Model). The introduction of the transactors will be advantageous in this regard. From the perspective of the beneficiaries, the transactors replace the authority to which under the current MAP applications are made for eligible RES-H devices. Furthermore small beneficiaries should submit more or less the same documents to the transactors as to the authorities under current conditions in order to be supported through the MAP. Furthermore bonus payments could be aggregated over several years so that operators of a small RES-H installation would receive funding for all their eligible RES-H generation by only few (e.g. two) payments. And the determination of the eligible RES-H volume (which is the basis for the payments) should be based on few standard plant parameters and simple calculation models (and not necessarily on measurements). Larger systems should underlie more stringent monitoring and documentation requirements, e.g. evidence of the quantity of RES-H produced should be provided every year on the basis of measurements.

The transactors claim the bonus payments from the obliged parties (see below). As a manageable number of companies will be concerned (approx. 1,000), each transactor can claim the bonus that is due from each of these companies in line with their individual obligations. Each obliged company is required to pay the bonus in accordance with its market share. In each case, the basis for determining bonus volumes and pertinent obligations consists of the last reference year, and in the interests of simplicity, the amounts and obligations are set by a federal authority on the basis of data gathered in the scope of the energy tax (see below).

The transactors' role entails substantial responsibility. In order to keep the system manageable the number of transactors should be limited (e.g. to around 12 organisations) whereas it is ensured that transactor services are offered throughout the whole country. The transactors process the applications submitted by beneficiaries for bonus payments, check them and then enforce them (in private law) vis-à-vis the individual obliged companies. The transactors must ensure a high level of transparency in their dealings with these companies and are monitored by a federal authority. Finally, the transactors pass the boni on to the beneficiaries they are acting on behalf. Expenses for transactor services are paid by the beneficiaries through respective service fees.

Who should be obliged?

Obliged parties (who pay the bonus) should be selected primarily in accordance with the "polluter pays" principle. This is linked to the question to which extent different parties can be made responsible for the environmental impact and damage originating from activities in the heating sector in general. The answer on this question is manifold. Alongside the consumers of fossil fuels, the various levels of the fuel chain but also the manufacturers of heating systems that run on fossil fuels could be considered in this context. In addition to the "polluters pays" principle practicability criteria should be applied in order to minimise the transactions costs of the system.

In our recommended system the obligation is put on those companies that initially place environment damaging fuels for heating purposes on the market or supply them to consumers and which fall under the German Energy Tax Act (EnergieStG). In the case of oil the obligation will affect those companies which exploit oil in Germany or import it. In the case of gas those companies will be obliged that supply gas to final consumers. The obligation does not apply to fuels going to power plants for electricity generation (e.g. gas) or fuel which is used in the chemical industry for non-energetic processes (e.g. oil). In addition the bonus obligation applies only to the proportion of fuels that can be replaced by renewables.

Allocating the obligation at this specific group can apparently be well justified by the polluters "pays principle" but has another important advantage. Most data required for determining the specific bonus volumes each obliged company has to pay within a settlement period is available as it is already collected by the financial authorities within the energy tax system. This simplifies procedures to a considerable extent. In addition the Energy Tax Act applies similar exemptions as foreseen within the Bonus Model (e.g. for heat generation from fossil CHP systems). However the timeframes and organisational procedures stipulated in the Energy Tax Act must be taken into account and might cause some delays in processing the Bonus System.

Although the obligation is put on specific companies the costs of the promotion scheme will finally end by the consumer. Most likely the obliged companies will pass the additional costs deriving from the bonus payments on to their consumers which would lead to slightly higher fuel prices (in our calculations we assume an initial price increase of 0,1% compared to current fuel prices rising to approx. 2,8% in 2020). However, compared to the present funding framework this would constitute a shift in the funding philosophy as it will now be the consumer who is bearing the costs for RES-H support and not the tax-payer anymore (as it is currently the case under the MAP).

Conclusion

The redesign and improvement of the policy and regulatory framework for the market penetration of RES-H should be one of the key strategies within ambitious climate policy. In order to secure stable and reliable long-term support conditions and to avoid stop-and-go market developments new support instruments should be independent from public budgets. Of the many different budget-independent instruments which we have assessed and compared throughout our study, the Bonus Model was shown to be the most suitable instrument for the long-term expansion of RES-H, both from an energy-sector and an economic perspective.

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The Experience of Education in Solar Water Heating in Brazil

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Introduction

The energy availability is a basic factor for the development of the nations. In a world highly competitive and submitted to the globalization of the markets the energy it starts to be a strategically variable of development.

It is proven that for the technological development of the Brazilian energy sector with the implantation of the solar water heating, actions as regulatory laws and politics, tax incentives, special politics of financing or campaigns of spreading and promotion it only has a durable effect if basic infrastructure elements as the quality of manufacture, project and installation well will be developed.

The use of the solar water heating for residential systems comes growing annually in Brazil, for example the huge grow in the period of the years 2000 to 2006, the collecting area for 100 inhabitants it passed of 1.2 to 1.7 m². However, this number still small when is compared with countries like United States, Canada and some in Europe. It fits to stand out that, currently in Brazil, approximately 67% of the residences use instantaneous electric heaters for the water heating destined to the bath, which represents 24% of energy consumed for residential sector and 6% of total energy produced by the country.

For the dissemination of this technology sustainable and continuous form it is necessary to surpass the barrier of the correct installation and design of solar water systems, a time that a quality and thermal performance of the national products already are assured by the Brazilian Labelling Program for the Solar Water Heating Collectors and Thermal boilers by National Institute of Metrology, Normalization and Industrial Quality (INMETRO).

Due to great territorial extension of Brazil, it has being necessary a coordinated planning for qualification of technicians in installation and maintenance and the use of technologies which integrate the actions in whole country, conferring, thus, trustworthiness and guarantee in results to the market and in installed systems of solar water heating.

Government Actions

Ahead of these facts, governmental politics come being implemented to stimulate the use of the solar water heating in the country. In 1997, through a joint action it enters INMETRO, the Brazilian Association of Refrigeration, Air-Conditioning, Ventilation and Heating (ABRAVA) and the Group of Studies in Energy (GREEN), located in the – Pontifical Catholic University of Minas Gerais (PUC Minas), was created the Brazilian Solar Thermal Energy Reference Center, hosted in GREEN, and implemented the Brazilian Labelling Program, which represented a landmark of evolution and quality in the industrial sector of national solar water heating. Through a methodology of tests of efficiency and durability, the products are certified and receive a label from classification that presents the monthly production of energy of the equipment, allowing to the consumer to evaluate with more clarity which product will supply to the best cost/benefits relation to it. Still tied with the Brazilian Labelling Program, the products that present greater performance they are awardees and they receive a stamp of efficiency homologated for the Electric Energy Conservation National Program (PROCEL), that it seeks to promote the rationalization of the production and the consumption of electric energy, to eliminate wastefulness and to reduce the sector costs and investments.

With the objective to foment the development of the solar water heating sector, the Brazilian government comes adopting politics of tax incentives which exempt, the manufacturers of solar water heating systems, to collect taxes like Industrialized Products Tax (IPI) and Merchandises and Rendering of Services Tax (ICMS) which together totalizes an exemption of 25% approximately.

Another important action of the Brazilian government through an partnership between Eletrobras/PROCEL, United Nations Development Programme (PNUD), World Bank (BIRD) and Global Environment Facility (GEF), was the inauguration, in 17th of December, 2004, in GREEN, the Laboratory of Indoor Tests, which consisted in the implementation of the first Solar Simulator in Latin America. Its functioning allowed to greater agility in the tests of thermal efficiency and accompaniment of the production of solar collectors beyond other activities of research, such as tests of photovoltaic cells and modules and accelerated aging of materials like plastics and automotive paintings.

As presented previously, for the diffusion in a sustainable form of the use of the solar water heating it is necessary, government actions and programs of qualification that contemplate aspects of installation and projects of solar water heating systems.

Distance Learning

Answering to this necessity of the Brazilian solar water heating market, in 2001, the Laboratory GREEN, in partnership with PUC Minas Virtual (area of the University responsible for the distance learning courses) elaborated the first distance learning course in solar energy of the country. The acceptance was immediate, and the use of the technology and the Internet allowed approach and teach more than 360 engineers and others professionals to the subject in Brazil. Ahead of the success and the proportionate benefits for distance learning, the Federal Government Bank (Public Bank managed by the Brazilian Government) requested to GREEN, the elaboration of a course in solar energy for more than 200 engineers of the Bank for all over the country. The objective was auxiliary them in the correct specification and analysis of projects of solar water heating systems financed by the institution.

SolBrasil Project

In 2005, it was approved with the Ministry of Sciences and Technology (MCT), through the Studies and Projects Financier (FINEP), the SOLBRASIL program, coordinated by GREEN in a partnership with ABRAVA. This program has the objective to spread out the knowledge in solar water heating in the whole country.

One of the sub-projects of this huge program, in first stage, aims to teach approximately 100 professors from 11 National Service of Industrial Learning (SENAIs), two Federal Center of Technological Education (CEFETs) and 4 universities distributed in different regions of the country. The first phase of the program will be in presence classes, where the professors of the institutions will receive practical and theoretical training. The pre-selected institutions will receive a didactic material composed from a manual contend technical information and peculiarities of applications in solar water heating in different regions of the country, a DVD with videos and animations approaching aspects of installation and security, a manual to practical lessons and three didactic groups of benches with objective to simulate and to present the particularities of solar water systems that operate in natural circulation (thermosiphon), pumped circulation and swimming pool solar water heating, represented in Fig. 1 and 2.

After concluded the stage of theoretical and practical qualification, assisted by the professors, the more important collected data will be raised than they will go to compose the manual of the students.

The second phase of the program consist to following and give technical support in the centers of qualification in the specific demands of each course, to promote forums of quarrel, distance meetings and to supply didactic material. This structure will be operated through a website that uses a specific technological resource for this application, allowing to the professors teach approximately 2000 engineers, architects, installers and other professional of the sector in Brazil.

All the qualification professionals, inside the SolBrasil Program, will be registered in the website with intention to establish a data base that integrates the professionals of the sector for future pedagogical and qualification actions, creating subsidies for the Brazilian Qualification Program of Solar Water Heating Installing Companies – Qualisol Program.

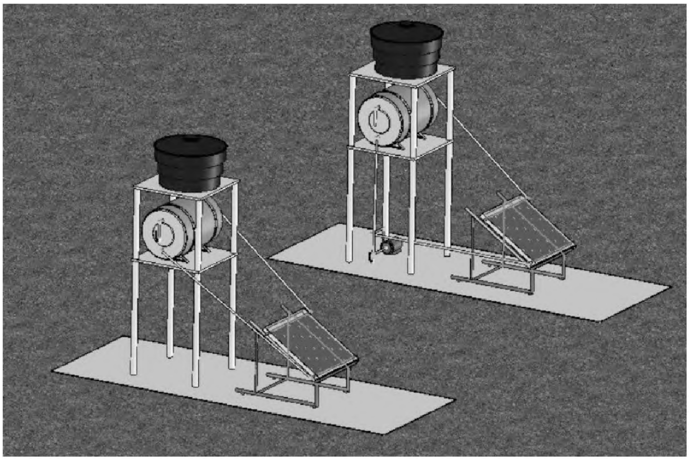

Fig. 1: Group of benches for natural circulation and pumped system

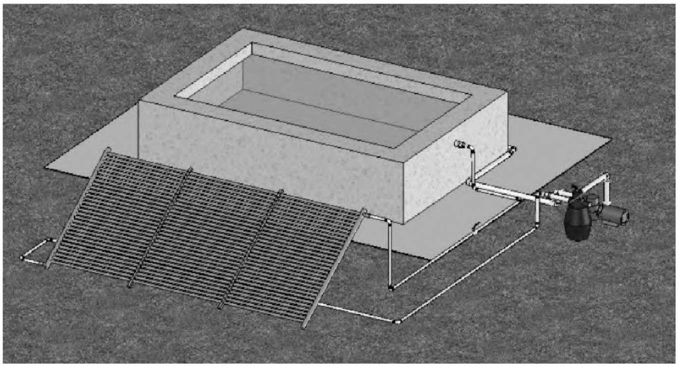

Fig. 2: Bench of solar water heating for swimming pool

Still inside the Program, GREEN will supply the same course in distance learning format to take care of the regions not contemplated initially in the National Net of Qualification in Solar Water Heating.

Technological Resources

As tool for operate the program it was adopted technology of website WSE – Workplace Service Express of IBM for supplying flexible accesses to documents, applicatory and allowing to customize for adequacy the necessities of the qualification program, through diverse interactive resources as integrated calendar, tasks, shared library, forums, room of quarrels and etc. Integrated to this technology, the chosen software to operate the system was the Lotus Notes, also of IBM, that allows using of its resources being the user hardwired or not to the net.

Conclusions

Great part of qualification actions in solar water heating in Brazil had only been presented viable through the use of technologies that allowed distance action integration and education through the use of technological tools that could be operated by the Internet. In such a way, we would like to tank FINEP, for making possible the implantation of SOLBRASIL Program, which together with other qualification programs, allows the growth of the solar water heating sector in the country with quality and in supported way.

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SOLATERM
A new generation of solar thermal systems for the Southern Mediterranean region

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Introduction

The countries of the Southern Mediterranean region are confronted with a rapidly increasing energy demand caused by economic and demografic growth. At the same time the region has a great potential for the use of renewable energies notably solar energy due to its high level of solar radiation.

The climatic conditions in the Southern Mediterranean region are favourable for the application of complex solar thermal systems but barriers exist due to high prices and a lack of technologies adapted to the specific needs of the region.

Solaterm combines the technological know-how of EU research institutions with the specific regional experiences and knowledge of the Southern Mediterranean partners on the use of solar. Energy agencies and administrations focussing on the political framework conditions complete the network of 18 partners from 8 Southern Mediterranean countries and 5 EU countries. The project consortium involves institutions and experts from Algeria, Cyprus, Egypt, Germany, Greece, Jordan, Lebanon, Malta, Morocco, Palestinian Territories, Spain, Syria, and Tunisia. Solaterm is financed by the 6th Framework Programme for Research and Development of the EU and coordinated by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.

Project Objectives

Solaterm aims at the widespread application of a new generation of solar systems for hot water, heating and cooling in the Southern Mediterranean partner countries. This includes in the first place the transfer of solar thermal technological know-how and the adaptation of new technologies to the specific needs of the Southern Mediterranean countries, secondly to promote cost-effective solutions and thirdly to support the political will in the region to develop renewable energies.

Project Outputs

Since the project start in 2006, the project partners have been involved in producing the following project outputs:

- *Framework Conditions Report*: Information and analyses of the current framework conditions for solar thermal in the Southern Mediterranean countries are collected, updated and published in a joint report. The Solaterm network develops recommendations to improve the conditions for the use of solar thermal technologies.
- *Technological Potential Analysis*: Solar thermal technologies are assessed according to their potential for a market uptake in the Southern Mediterranean region.
- *Energy Concepts: Case* studies on solar thermal energy supply for selected buildings which are equipped with exemplary systems are elaborated resulting in guidelines for planning and dimensioning of solar thermal systems.
- *Know-how Transfer*: Central instruments for know-how exchange are mutual expert missions and internships in the partner institutions with the aim to support the development of new pilot projects.
- *Networking*: The project is designed to bring together actors from EU and the Southern Mediterranean participating in solar thermal research. A vital exchange on specific technologies e.g. high efficient solar collectors, solar cooling, combined systems for solar water and space heating is taking place in working groups.

Project Events

The findings from the analysis of framework conditions and the technological potentials for solar thermal in the Southern Mediterranean Region are presented during a Solaterm Conference in Marakesh, Morocco in October 2007. The conference will formulate policy recommendations and it will address business opportunities for solar thermal applications in a specific panel.

In September 2008 a Conference is planned in Jordan summarizing the results of the Solaterm project.

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Strategy on Market Penetration of Solar Water Heaters in Pakistan

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Project Background

The Government of Pakistan and the German Ministry for Economic Co-operation and Development (BMZ) have formally approved the Pakistan-German Renewable Energy and Energy Efficiency (REEE) Technical Co-operation Program. The program has recently initiated its first activities with the main partners: Alternative Energy Development Board (AEDB) and National Energy Conservation Centre (ENERCON), Ministry of Environment and German Technology Cooperation (GTZ).
Part of this program is the market penetration of Solar Water Heaters (SWH) in Pakistan.

Pakistan meets its water heating needs for domestic, commercial and industrial usage; through mainly natural gas, but also electricity, fire wood, coal, LPG and cow-dung in rural areas. The country has in total over 4.4 million natural gas connections. Majority of them are domestic ones in urban areas, whose use maximize in winter months for additional space heating.

Future Solar Water Heater (SWH) market segments can be seen:

- 159.5 million population with an average household size of 7 persons.
- Pre-heating requirements at various commercial and industrial levels
- The existance of promising solar legislation in the country ensures a potential market for SWH as alternative energy source.
- Besides efforts on the use of RE, conservation of conventional sources take place.

STRATEGY

The country will face a growing gape between energy demand and supply in the coming years. To face this growing energy demand, the Government of Pakistan will introduce an *act* on the mandatory installation of SWH for new buildings as part of the national REEE-program.

In order to make the act successfully the market must grow to a sufficient production capacity to serve the created demand.

Currently only a few companies are producing SWH in small quantities. But demand will also rise with increasing energy costs and growing economic development.

A working group from across the country representing all concerned stakeholders was formed, who is regularly giving its inputs for the promotion and development of SWH.

The projects cooperates with the relevant stakeholders through: developing national SWH standards, testing facility, product certification, technical support to the designers and manufacturers, training of plumbers, awareness campaign though demonstration projects, market creation and not but the least customer satisfaction.

Quality assurance is of utmost importance for satisfying the customer's needs. Therefore adequate national standards are under preparation and a testing facility according to international standards (ISO) is under construction in Islamabad. Manufacturers of SWH get advice from GTZ and AEDB resulting in quality improvement on their products.

Supplier and plumbers have to be *trained* on quality and service provision of SWH. Qualified management that include the whole range from system design to installation, maintenance and repair have to be made available in all regions concerned by the act.

SWH industry is at the initial point in Pakistan and therefore the market has to be developed step by step. Promotion on the use of solar water heaters is currently underway with innovative projects related to customer needs and social behaviour.

PILOT PROJECTS

GTZ has signed a public-private-partnership (PPP) with TOTAL PARCO PAKISTAN (TPPL) Limited in July 2006. The project in collaboration with AEDB is providing technical support for the implementation of SunWash® facility at TPPLs fuel stations for washing the cars with solar heated water (see Fig. 1). This PPP has the objective to strengthen the local SWH market and creating awareness on SWH. Advertisement campaigns with the brand-name SunWash® rise customer awareness not only for improved car wash but also for the applications of SWH on the customer's side. The first pilot scheme was commissioned and inaugurated in November 2006 at Rawalpindi.

Fig. 1: Fuel station in Rawalpindi with SunWash® facility for car wash.

A community project has also initiated in cooperation with the local district government of Chackwal region. This project supports the installation of SWH on the roof of mosques in rural villages with the primary objective of awareness. People need hot water for washing before prayer. The SWH can provide this service and is visible from outside of this community building and will raise awareness for the domestic use of SWH. The training of plumbers will come along within these installations.

Further support is given to the National University of Science and Technology (NUST) for the planning and designing of a 400 m^2 industrial pre-heating SWH project as a demonstration project in a leather factory in the city of Lahore. High demand for SWH in the textile and leather manufacturing sector of Pakistan can be seen in future with high consumption of hot water and steam.

Further impacts already achieve

- The manufacturers are sending their solar collectors for testing of the efficiency and quality test at Pakistan Council for Renewable Energy Technologies (PCRET) already.
- The national standards are introduced (in accordance with ISO standards) and will be adopted by all the manufacturers and suppliers of SWH.
- After the success of first locally manufactured SunWash® at a fuel station in Rawalpindi, TOTAL Parco currently install a second SunWash® in Lahore.

- Other fuel companies have also shown interest to go for SWH at its car wash facilities.
- Gas provider has also started planning how to introduce SWH to its domestic gas consumers for water heating in a contract scheme.

Fig. 2: SWH installation on a mosque in the Chackwal district for washing before prayer.

Solar Thermal ESCOs as a solar thermal market developers: first examples in Italy

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INTRODUCTION

The market of solar thermal systems in Italy finally managed to reach a capacity comparable to the other European Mediterranean countries (i.e., about 130 MW_{th}.) [1]. The larger part of the Italian market is constituted of small systems and average costs are higher than other European countries.

The solar thermal Energy Service Companies (ST-ESCOs) can be a very important player in a developing market. The ESCO scheme foresees the following actions: Plant's financing, through TPF or by own capital; Design, supply and installation of the system; plant operation and produced energy sale. Due to the current boundary conditions in Europe (energy price, solar thermal technology cost, etc.) there are some applications where the model allows the ESCO to create profit from the invested capital.

The important characteristics of this kind of scheme, in particular for the Italian market, is due to: Guarantee the durability of the plant for the whole (long term) contract duration); the Realization of medium/large scale plants; Financing of the investment, (often a barrier for the development of solar thermal market, especially for large scale plants); Simplification of the management of the whole project, being the ESCO the only reference company for the customer (it manages the contacts and the project development with installers, suppliers, banks, etc.).

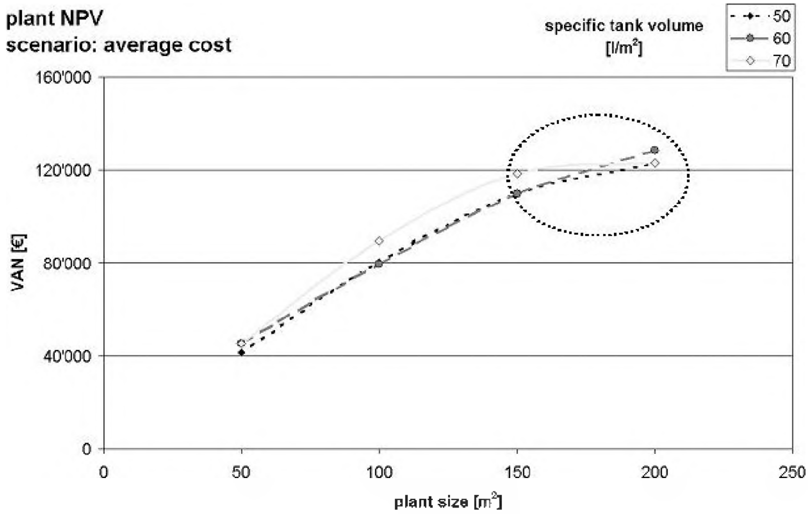
The present article will examine the main elements for three realization of an ST-ESCO project in Italy, in order to show the potential of the scheme in different cases and applications.

CRITERIA FOR THE DEFINITION OF AN ST-ESCO'S PROJECT

DIMENSIONAL OPTIMIZATION OF THE PLANT

Starting from the defined heat demand profile and plant configuration, the energy performance of the plant is simulated for different solutions of collector field size (m^2) and tank volume (total, m^3 or specific, l/m^2_{coll}), considering existing constraints.

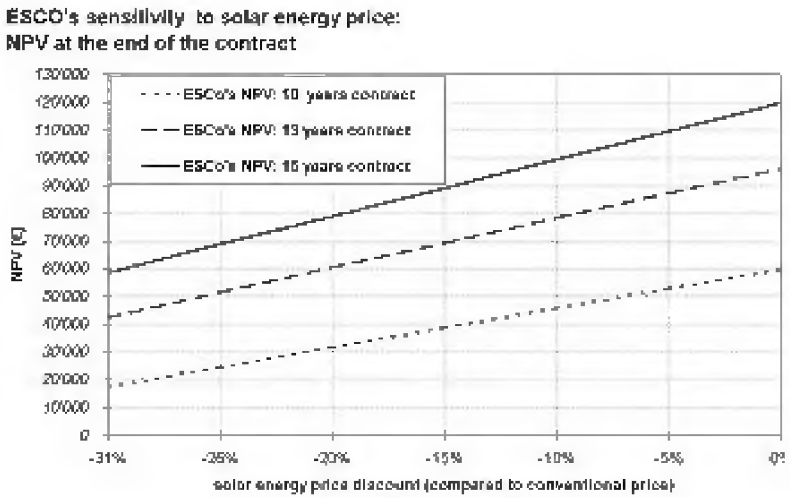
The specific production data are used for a preliminary economic analysis of the investment. Assuming average market values for the plant's component costs, fuel cost (assuming a growth rate and actualisation rate) the NPV is estimated at the end of the plant life (usually 20 years). In order to implement a pre-selection of the most performing systems for the ST-ESCO application the top 15% of the NPV area has been considered. As shown in the graph where the best economic combination of plant size/tank volume are highlighted.



Economic evaluation and contractual hypothesis

Starting from these values, the precise definition of the plant is obtained considering the boundary conditions. The simulation of the chosen system gives the awaited producibility of the plant. For the precise definition of the economic analysis it's necessary to consider (at least) the following external parameters: Conventional energy cost, (including the conventional system efficiency); Cost of the money and inflation rate; Kind of financing (initial investment or loan); Incentives and subsidies; Percentage of end user's investment (it's usually at least the 15%, to cover the non-hardware costs of the plant, in order to minimize the risk for the ESCO).

Further a sensitivity analysis of the profits (NPV), both for ESCO and end-user, is carried out in respect to solar energy price (€/kWh) and length of the contract (years). Evaluating the most significant economic parameter (e.g. NPV, PBT, IRR) at the end of the contract, it's possible to define the possible couple of values energy-price/contract-length to propose to the customer.



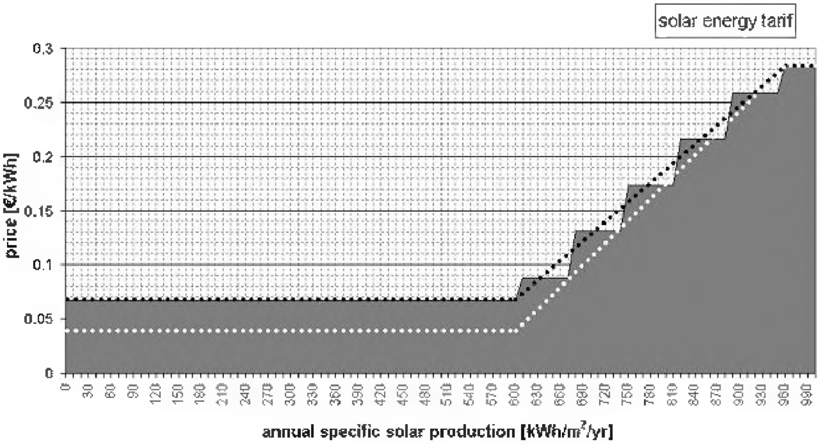
Case study #1: DHW production for a sport center in Lombardy (Italy)

This first ST-ESCO project presented is related to a public sport facility. The aim was to prepare a solar thermal energy service call for tender for the DHW production in a sport center (2 swimming pools, summer and winter and a gymnasium). The annual energy demand for DHW was considerable, about 420 MWh, with a significant reduction in summer (15–20 MWh/month, instead of 35–45 MWh/month for the rest of the year). At the moment the municipality has a gas supply contract valid for the whole facilities which will go on also after the solar plant installation. For this reason the solar plant will be installed separately from the rest of the existing thermal plant, serving as pre-heating of the cold water. With this solution, in fact, it's possible to clearly define the responsibilities of the ESCO and the company which manages the old plant. Under these condition the expected dimension of the plant is around 180 m². The call for tender has been defined trying to minimize the constraints for the ESCOs. It is imposed: Dimension of the technical room; Minimum annual production of the plant; Installation of a "custom built" system, with certified collectors (EN 12975) and a range size from 140 to 220 m² according to the Italian standards and regulations.

All the other parameters, size of the collector field, configuration, tank volume, type of collectors, connection to the existing system, are set free and will be chosen by the ESCO who will win the call for tender. The guarantee for the correct operation of the system is the ESCO scheme itself, while the ESCO earnings are directly related to its energy production. The guarantee for the quality of the installation is given by the *tender* mechanism. The only parameter, used for the selection of the tender is the solar energy tariff, according to a mechanisms described further. In particular the price the municipality will pay to the service provider, after a certain threshold, will grow with the specific energy production. The tariff curve is defined as follows:

- Constant for the first interval, from 0 to 600 kWh/m²/yr, at the *tender value;*
- Constant at 0.284 €/kWh for production over the 950 kWh/m²/yr.
- Linear growing between 600 to 950 kWh/m²/yr, the latter is the maximum value granted;

The figure show the tariff curve and as example the effect of a 40% reduction, from the base price, of the solar energy tariff due to the tender (white bulleted). Such a tariff mechanism should push the ESCO to realize a plant with good quality component, since the reduction of price for the base specific production (up to 600 kWh/m² y) is compensated by the increased cost for the growing specific energy production.



The base data for the tender has been obtained from the economic simulations, considering a 10 years contract (defined by the Municipality) and an energy price curve that guarantees, at simulation conditions (specific producibility: 780 kWh/m²/yr, system cost: 650 €/kWh), a PBT of less than 9 years and a IRR of more than 10% for the ESCO, and 5% savings for the Municipality from the beginning. As guarantee for the ESCo it has been defined a minimum monthly heat load by the Municipality, apart from the reference load profile used for the simulation. The project is co-financed for the 50%, thanks to facilities dedicated by the Lombardy Region for solar thermal installation in Public buildings.

Case study #2: ACS Production for a MFH (Casa Ecologica, Milan)

This case show a retrofit project in a residential building (109 flats), with good boundary conditions (centralized DHW production plant, south facing roof). During the plant design phase it has been decided to use the existing tanks (10 m³), in order to simplify the integration, the installation and the management. Through economic analysis, it has been defined a 140 m² flat plate collector field.

Contract period t (years)	NPV_t [€]	PBT [years]	IRR_t
9	-15'167	12.3	1.1%
10	-10'081	12.2	3.5%
11	-5'062	12.1	5.4%
12	-110	12.0	7.0%
13	4'774	11.9	8.2%
14	9'592	11.8	9.3%
15	14'343	11.7	10.2%

This fact reduced at only 30% the solar fraction, with an annual production of about 95 MWh/yr and a specific production of 680 kWh/m²/yr.

The ESCO also stipulated a trade agreement with a local bank to obtain prime rate loans and with a collector supplier. Even so these good conditions, the economic results show that, at the current energy cost, the minimum contract length is about 14 years. This is due to two important elements: the low cost of the fuel substituted (natural gas) and there absence of subsidies available for ESCOs.

Case study #3: process heat for a dairy industry

The third case presented has significantly favourable boundary conditions: The thermal load is high, about 500 MWh/yr, and roughly constant through the all year (between 36 to 44 MWh/month); The solar radiation is significant, about 1400 kWh/m²/annum (on the horizontal); The convention energy cost is very high, due to the fact that the used fuel is LPG and the system is not energy efficient; the heat production is made by a couple of steam generator, for low temperature uses too.

Two different hypothesis have been foreseen:

- Water pre-heating before inlet to steam generators: the system is characterized by a simple system integration, but solar faction is low, due to the fact that heat is provided by the steam generators;
- Direct utilization of solar heated water for low temperature uses: In this case an higher integration complexity furnish an improvement of the energy behavior of the system and operate in a temperature level more appropriate to a solar system.

As it was foreseen, the second typology of intervention offer the possibility of install a solar field of medium dimension of about 150 m².

Economic conditions of the intervention are improved by the propose of the ESCO to stipulate a commercial agreement with a local solar collector producer and with some local installers, which is not possible to quantify until now.

CONCLUSIONS

A methodology of analysis for ST-ESCO projects has been developed (in the EIE project ST-ESCO) and has been here shortly presented. In some cases and ESCO model results economically feasible and could theoretically be applied with success, as shown in the three cases studies. The 2007 Italian financial law introduced a tax reduction mechanisms for energy efficiency measures. In particular installing solar thermal technologies a tax reduction of 55% of the whole system costs is applied. The mechanisms, straight forward for a private person, does not particularly easily applies for an ESCO. Therefore among the studies presented the cases 2 and 3 will be realized not following an ESCO model but simply supply the system. This kind of incentive is a really effective measure, but without paying attention to service company, it could avoid the development of ESCO's projects.

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SOLCAMP – Solar Energy for Camping Sites

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Introduction

Today there is no doubt that camping sites represent one of the most suitable applications for solar thermal systems. Not only the hot water demand at camping sites and the solar energy supply coincide almost perfectly – during the peak season from May until October approx. 75% of annual insulation occurs – but also the owners and clients of camping sites show environmentally friendly behaviour and are in the most cases promoters of sustainable development at local level. It need not to be stressed, that the solar thermal systems at camping sites serve as good demonstration models for the clients thus contributing themselves as multipliers to further diffusion of this technology.

Overall objective

The overall objective of proposed activity is to create, to implement and to monitor a campaign for increased use of solar thermal systems at camping sites. To achieve this goal a standardised, neutral consultant tool, the "SolarCheckCamping" has been developed to provide the camping site owners with independent information on solar thermal systems and with the planning data for their site free of sales interests.

A "SolarCheckCamping" tool simulation software has been developed and in each of the participating regions "SolarCheckers" have been trained. Increasing of penetration of solar thermal systems at camping sites will convince the guests by making positive experience also to invest in such systems, thus contributing to further dissemination of solar energy use.

Conclusion

The SOLCAMP project, supported by the European Commission within the frame of the Intelligent Energy Europe programme, will help to increase the use of solar thermal techniques on camping sites – a market predestinated for this application.

A set of useful tools have been developed for the consulting and planning of solar thermal systems adapted to the specific boundary conditions at a camping sites.

Solar thermal market promotion – the example of Upper Austria

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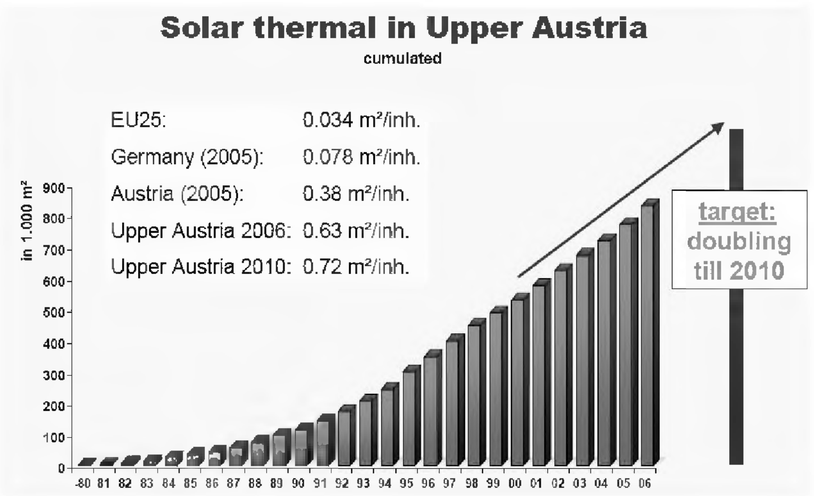
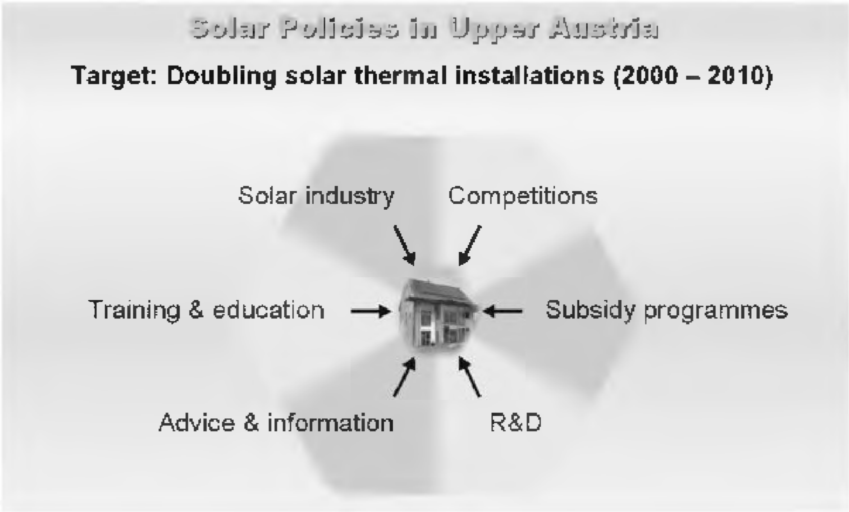
Background & Approach



Presently, 800,000 m² solar thermal collectors are installed in the region of Upper Austria which is more than 570 m² per 1,000 inhabitant. This favourable development is a result of the implementation of the Upper Austrian energy strategy and action plan in the past 12 years. However, the successful market development so far took place mainly in the residential sector with every 2.5 newly built home being equipped with solar thermal collectors. The solar campaign which was started last summer by the O.Ö. Energiesparverband, the energy agency of Upper Austria, aims at bringing this development also to the large-scale solar market.



Solar thermal awareness raising campaign – main activities

A number of programmes are implemented by creating demand for solar energy products & services and by supporting the market in meeting this demand, including among others:

- *Solar campaign 2005 & 2006*: a "solar-hotline", targeted information brochures (e.g. one for the hotel business sector) and large-scale "solar bill boards" which were posted all over the region. About 150 installers and all main solar companies in Upper Austria took part in the campaign.
- *Training*: training seminar for the design and implementation of large-scale solar thermal plants
- *Seminars & events*: a number of well-targeted events put the focus on large-scale solar thermal plants, e.g. information event for installers including an exhibition of leading solar companies

- *Competitions*: competitions for the different target groups were organised, including:
  - a regional solar league awarding the best "solar municipalities"
  - a competition on low energy (apartment) buildings (target group housing associations)
  - a competition on sustainable energy targeting at households, public bodies and companies
- *Energy efficient company buildings*: one focus of the campaign are energy efficient company buildings using sustainable energy which are supported by on-spot energy advice (up to 2 days), best practice examples and online platform information (list of planners, etc.)
- *Supporting the solar energy industry*: business development is supported by a network of "green energy companies" (144 members, more than 476 M€ turnover, 3,200 employees)
- *R&D initiatives*: regional Energy Technology Programme (about 110 R&D projects in the fields of energy efficiency and RES in Upper Austria supported).

Solar Thermal and Other Energy Efficient Heating Solutions. Will Europe Follow Germany's Lead?

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INTRODUCTION

The European heating sector is currently undergoing profound changes, and the patterns of change are varied, reflecting the diversity of the countries involved.

The major drivers of change in recent years have been legislative initiatives (at national or at EU level) and product related incentives and subsidies. Within the EU, the timeframe for achieving results has recently shifted from the Kyoto targets to the commitment to make 20% savings by 2020. The interest of legislators in domestic heating has increased and it is almost inevitable that this sector will be expected to offer at least a proportional share of the targeted savings.

Solar thermal so far has benefited from both legislation and incentive schemes. It is a general perception that these will support the growth of solar thermal until it reaches a critical mass and becomes an almost universally utilised technology.

It should however be noted that the use of solar thermal for heating at present is rarely justifiable on a purely economic basis, as payback periods are still rather long. Competition for investment in heating is likely to intensify in the near future, and other energy saving measures with a shorter payback may find themselves preferred. It is then possible that the great popularity that solar thermal is enjoying in a number of European countries will not be replicated in neighbouring markets.

Several technological solutions are at the centre of the debate on how to improve efficiency in domestic heating. They include:

– products (condensing or at least "low temperature" modulating boilers, biomass heating, hydronic heat pumps, developing embryonic technologies such as micro-CHP and gas heat pumps, solar thermal) and
– systems (collective forms of heating – including district heating/CHP, block and single building heating – improved insulation combined with suitable heating controls, underfloor heating combined with low temperature boilers).

This diversity of options is matched by national diversities, involving:

- differences of climate, culture, energy resources, wealth and general environmental consciousness between the countries. This is reflected in past approaches to energy efficiency (practices, legislation, incentives)
- differences in the reach of natural gas networks, local availability of fuels, mix of electricity supply
- differences in the stock of heating systems (district, collective, individual, dry system, non-central heating).

While the EU Commission's Eco-Design process might aim for the harmonisation of minimum performance standards across the EU, the Energy Performance of Buildings Directive (EPBD) leaves each Member State to use different means. Thus the approach to energy saving in heating is likely to continue to be diverse. To give some examples:

- Germany has long been the champion of low temperature heating, weather controls and TRV's and underfloor heating. It is only over the past 10 years that condensing technology has been wholeheartedly embraced
- it is the Netherlands that have long championed condensing boilers, starting a movement that has spread to many countries (most dramatically to the UK)
- Denmark, Sweden, Finland and Austria have been investing in advanced district heating systems
- Sweden has been the leader in heat pumps
- the UK and Netherlands appear to be the greatest enthusiasts for micro-CHP

Concerning solar thermal it is probably necessary to distinguish between:

- the Mediterranean countries, with Turkey, Cyprus and Greece as the established users (mainly of gravity systems for water heating), and Spain, Italy and Portugal now adopting EPBD-linked legislation
- central and northern Europe, with Germany and Austria as the most advanced markets, especially for pressurised water heating and combined systems
- the USA, where (apart from unglazed systems for swimming pools) much of the household demand is for the replacement of old systems.

At the other end of the environmental spectrum:

- the district heating systems of eastern Europe (especially Russia and Ukraine) probably account for the greatest waste of energy in all European heating
- the USA is a massive per capita consumer of energy for home heating, and warm air systems (even using condensing furnaces) must be partly responsible.

The Stern Report called climate change "the greatest market failure the world has ever seen". One clear message to come out of the BRG CONSULT research (see below) is that there is no solution that can make a sufficient difference which can intrinsically be justified solely on economic grounds, i.e. be left to the market place (apart from changing attitudes and perhaps encouraging better insulation and use of simple heating controls). *Finding adequate solutions will require substantial investment of public funds, supported by a willingness of households to make some sacrifices (voluntarily or via legislative coercion).*

The message is that solar thermal needs to compete with other energy saving solutions for over-stretched funding.

The total European market for solar thermal in 2005 comprised an estimated 550,000 systems (from c. 300,000 systems in 2000; compounded yearly growth c. 13% 2000–2005), of which 8% was combined and 92% water heating only (compared to 2% combined and 98% water heating only in 2000). Roughly one third of system sales in 2005 were pressurised and two-thirds gravity. The German speaking countries are the main drivers of demand for pressurised systems and are behind the growth of combined systems. Germany is easily the largest non-Mediterranean market, and on a per capita basis Austria is also highly developed.

It is thus worth exploring some of the issues that might determine whether other countries in Europe will follow the lead of Germany and Austria.

First of all, it needs to be recognised that Germany is not typical. The success of the MSP (MAP) programme launched in 1999 was based on a combination of the incentives offered and a cultural receptivity, reflecting a highly developed environmental consciousness and a concern about the future security of energy supply. Even with the incentives on offer, payback projections hardly looked inviting.

Forecasts for the future of solar thermal in Germany tend to be very positive, with suggestions that the market in m^2 will grow by a further factor of 5 or more by 2020. However, even in recent years the growth has been erratic. The number of systems sold in 2005 was still running below the 2001 level, with the market having dipped in 2002 and then recovered. The surge in 2006 may have been in anticipation of the hiatus in subsidies and VAT rates that occurred at the end of the year, and by April 2007 there were reports of sales going into reverse. The next 6 months may prove to be critical.

In most of the rest of Europe, support for solar thermal is far more hesitant. Politicians love to talk about it along with other renewables, but payback tends to be uppermost in the minds of those expected to invest in it. Even in Mediterranean countries such as Spain, Italy and Portugal that are being obliged to invest more in solar by EPBD linked legislation, we have found a good deal of scepticism. Further north, the scepticism is even greater, with doubts about whether solar thermal is suited at all to climates where the greatest need is when there is the least sunshine. Solar thermal is widely perceived as a supplementary technology, able to make a significant contribution to water heating and a more marginal one to space heating.

This said, solar thermal does fit nicely into the EPBD holistic approach to energy management in buildings, and this should ensure a growth in demand over the next few years from new construction (especially collective housing where buffer storage facilities can be shared).

The big question is how things will develop in about 5 years' time. The solar thermal industry's vision, as set out in the publicity for this Conference, is of "most new buildings in Europe being entirely heated by solar by 2030". By contrast, we foresee a period of disillusion setting in about 5 years from now, when politicians realise they are not achieving the required emissions savings from their favoured technologies, and householders find they are not getting the paybacks they had hoped for. This could lead to a shift in public funding:

- away from new build towards the existing dwelling stock (in 2020 homes built after 2006 will only account for 15% of the total dwelling stock)
- away from marginal technologies towards the established mass market (even in Germany solar thermal is installed in only 2% of dwellings).

This is not to say that there will be no place for solar: good environmental practice in building is an investment for the future. But if the emission reductions targets are to be met by 2020, something on a larger scale will be needed, such as:

- Europewide improvements in *insulation and heating controls* in existing dwellings (not so urgent in Germany as in most other European countries)
- targeted and accelerated *replacements of old boilers with more efficient ones*
- remodelling of the East European *district heating* networks, and possibly more investment in CHP in other countries.

Any such solutions are likely to need more funding than will be generated from the market place alone, or indeed than is currently being offered from the public purse. Stern suggests that to act quickly might only cost 1% of global GDP. That 1% needs to be made available and invested judiciously.

Conclusion

There are many possible approaches and technologies available to help reduce energy consumption and CO_2 emissions from home heating, and the markets for these are being explored by BRG CONSULT in a major new multi-client research programme entitled "Study on Eco-Related Developments in the Domestic Heating Markets in 30 European Countries and the USA 2006/7". Due to be completed in June 2007, this study follows on from some 25 years of researching European heating product markets, as well as BRG CONSULT's recent involvement in the EU Commission's Boiler Market Study and Eco-Design projects on boilers and water heaters.

Strategic Partnerships between Spanish and Foreign Solar Thermal Firms

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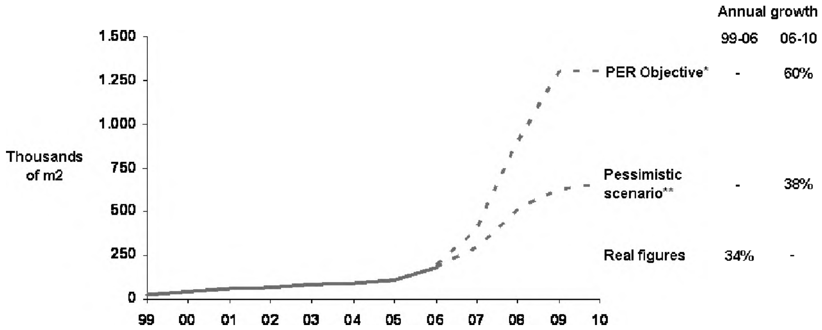
Introduction

Over the last few years we have seen several acquisitions of Spanish firms by German players in the photovoltaic (PV) industry. It is likely that the Solar Thermal (ST) industry will also experience this kind of consolidation shortly. eclareon has been exposed to this kind of deals.

Why the Spanish market is attractive to foreign ST companies

The Spanish market is expected to boom over the next years. The publication of the new building standards (Código Técnico de la Edificación, CTE) creates expectations for a large market to arise. Market growth will be driven mainly by the volume of new dwellings, which will lead to an annual market volume in 2010 of between 0,7 and 1,3 millions square meters.

Estimate of annual ST market in Spain



Note: *Plan de Energías Renovables, 2004-2010;
**Pessimistic scenario: reduction in the rate of new housing starts, 85% of maximum penetration of CTE only reached in 2010
Source: PER (Plan Energías Renovables), eclareon analysis

Given the past market development, the expected growth rate implies that companies approaching the Spanish market should be fast when deploying their entry strategies.

The expected growth will attract foreign players (mainly German). Some foreign players hold significant advantages in front of local players, which creates good opportunities for collaboration, but experience shows that local staff with specific industry background is highly recommendable in order to achieve a successful market entry.

Understanding the Spanish market: issues to be taken into account

Legal framework

Legislation has been a key demand generator so far and it will need to be taken into account to understand future development. Even if available public subsidies are fading out, they could still play a role. Some voices are warning about the hypothetical limitations of the CTE in creating a robust market where quality ST systems represent a real contribution to energy saving. If these hypotheses turn out to be true, changes in the current system are to be expected.

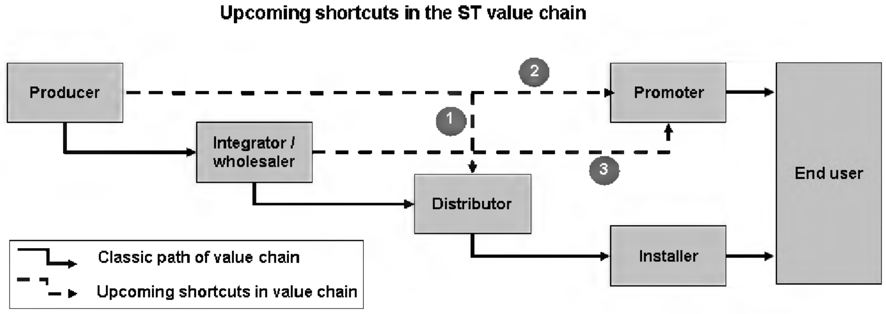
Certification has been so far a barrier for foreign players arriving to Spain. Collector homologation was mandatory if public subsidies were to be granted. For several years the only valid institute to conduct these tests was INTA. This monopoly created undesirable consequences such as:

- The homologation process lasted for several months
- Results obtained were in many cases significantly different from those obtained in other European institutes, which created confusion

The recent publication of the RD 47/2007 will change this situation, as homologation tests from other European institutes will finally be accepted by Spanish authorities.

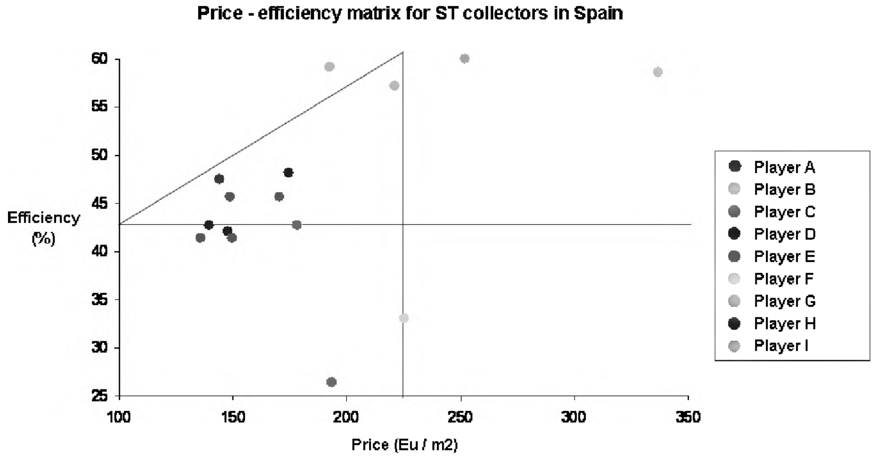
Specific items of the Spanish market: product, clients and distribution

ST firms in the Spanish market have traditionally been producers (or importers) covering all steps of the value chain. As the market developed, companies specialised within each different stage of the value chain. Some companies became vertically integrated. The arrival of the CTE and the proximity to the building industry has created several shortcuts across the value chain. Promoters (and their general contractors) and generalist wholesalers have become key pieces of the ST puzzle given their bargaining power. This fact is currently modifying the classic structure of the value chain.



Source: eclareon analysis

When adopting a position within the value chain, product specificities should be taken into account. Different customer motivation generates different product policies to be adopted. Product policy and position in value chain should be combined in order to achieve a successful commercial strategy. When such a policy is designed for the Spanish ST market, the participation of a local player can generate significant benefits.

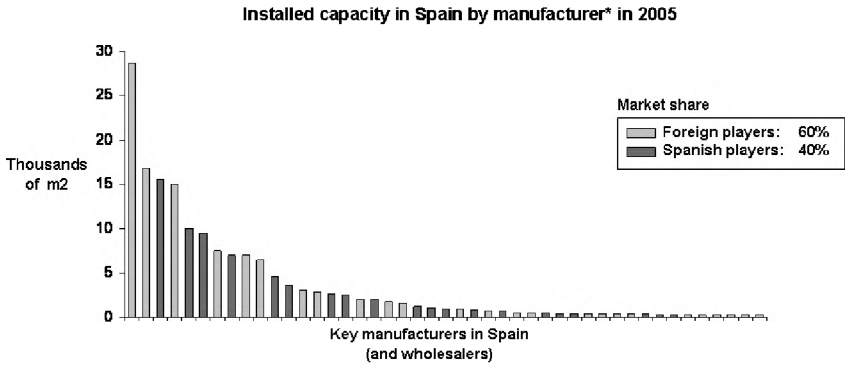


Source: eclareon

In a market where quality is not appearing as a key purchasing criterion, price and distribution appear as key elements to achieve high market penetration. In order to achieve a capillary and well positioned sales force, an agreement with a local player could be the best option.

INDUSTRY ANALYSIS: DIFFERENT GROUPS OF PLAYERS

The Spanish market is already populated by foreign players, mainly arriving from Germany. However we still see space for companies to grow through acquisitions.



Note: *We include the main producers, assemblers and distributors
Source: IDAE; eclareon intelligence

Each company's specific characteristics make it suitable or not for working together with a foreign company. A company thinking about acquiring a local firm should identify the most complementary target. Spanish firms tend to have a relatively attractive sales force and good market knowledge, but normally lack financial strength and a professional management. These are two classical areas where larger and most experienced firms can support a Spanish firm.

THE STRATEGIC PARTNERSHIP: ADVANTAGES AND PROCESS DESCRIPTION

The two main options when approaching a foreign market are starting a local subsidiary from scratch and acquiring a local firm. Both possibilities hold advantages and risks. Main advantages of acquiring a local player are:

- Proven working team
- Financial results from day 1
- Relatively short process

Main risks are:

- Price to pay is in the range of millions of Euros
- Post-merger fit between human groups

In order to minimize risks a proper analysis should be conducted before a decision is taken. In our experience, Spanish players are normally open to discussing a take-over or an alliance with a foreign player.

The steps to be taken in an acquisition process are:

1. Target screening
   - Creating candidate list
   - Selection of appropriate candidate according to relevant criteria

2. Commercial due diligence
   - Market analysis
   - Assessment of the competitive position of the firm within the market and expected potential
   - Check of internal issues relevant to value creation (management quality, staff ...)

3. Transaction negotiations
   - Estimate of price to pay (based on company valuation)
   - Price structure (fixed/variable price, put/call options ...)
   - Legal, tax and financial due diligence
   - Contract signing

Conclusion

Acquiring a local firm is an attractive option for a foreign ST player willing to

- Grow rapidly
- Build a well established sales force

Solar Graz – A new business approach

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1 Introduction

Solar Graz GmbH was founded in 2006 as a joint venture of Energie Graz, the public owned utility that serves Graz, Austria and S.O.L.I.D., a 15 year old private company that is recognized as a world leader in the design, manufacturing, installation and operation of large commercial solar thermal systems.

The primary focus of this unique partnership is to fully develop the potential of large scale commercial solar thermal which would result in Graz becoming the "solar capital of Europe". The plan includes using solar thermal to provide district heating, space cooling, process heat and domestic hot water and space heating in condominiums. To date S.O.L.I.D. has installed in Graz solar plants with a total capacity exceeding 4 MegaWatts.

We offer

- project development,
- engineering,
- delivery of key components,
- construction and
- operational support.

2 Our produkts

2.1 Sanitary hot water

The most widespread application of solar thermal is the production of domestic hot water (DHW). Typically solar collectors capture and store heat in a large water tank which insures that ample hot water is always available upon demand.

2.2 Space heating

Space heating can be provided by installing systems that are typically larger and more sophisticated than systems for DHW. These systems are very effective in displacing fossil fuels, particularly in the Fall and Spring when space heating is needed an solar radiation is strong.

2.3 Solar district heating

In central energy systems, solar can feed into the distribution net and provide either direct heat or preheat for make up water. All kinds of applications – pool heating, sanitary water, space heating, thermal chillers- can be provided for through the district heating system.

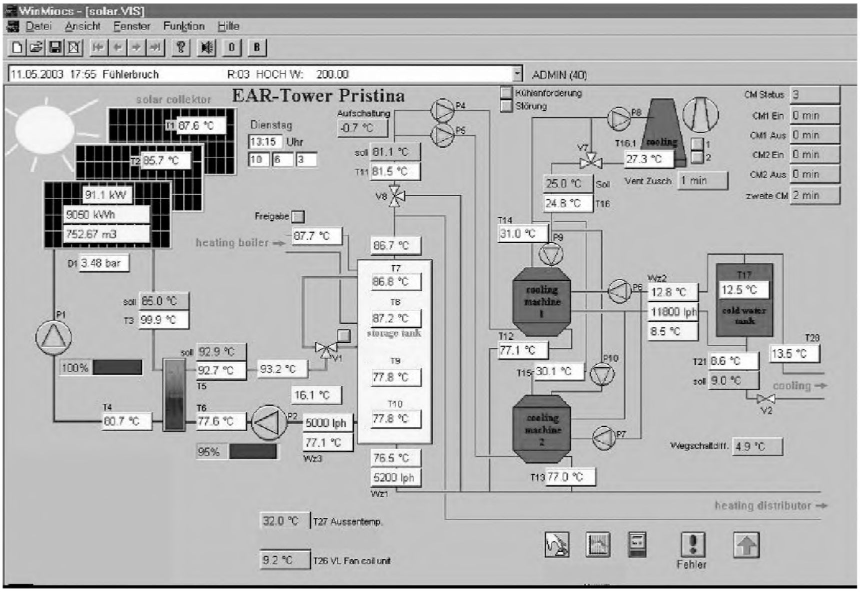
2.4 Process heat

A new emerging market is industrial process heat. Many processes such as those in the food or textile industry need temperatures between 50° and 100° C which is a perfect application for solar.

2.5 Solar Cooling

A highly promising application for solar thermal is emerging in a big way: Solar Cooling.

While heating demand is greatest in winter when solar availability is low, cooling demand is highest in summer when sunshine is plentiful. So, the energy from a solar plant can be fully utilized by sizing based on the summer demand for air conditioning and sanitary hot water, and using the system in winter to significantly reduce the need for space heating using fossil fuels.



3 Reference Plants of Solar Graz

3.1 Grottenhofstrasse – Sanitary hot water and space heating

Collector Field: 500 m²
Storage: 30 m³
Yield/Year: 200 MWh/year
Commissioning: 2007

The residential house "Grottenhofstrasse" with 188 apartments will be supplied with hot water and space heating by solar energy in combination with the district heating grid of Graz. During the summer season the majority of energy will be produced by the solar plant. In addition, the storage tank is used to reduce peak power demand from the district heating net.

3.2 Berlinger Ring – Sanitary hot water and space heating

Collector Field: 2417 m²
Storage: 60 m³
Yield/Year: 1000 MWh/year
Commissioning: 2003 to 2006

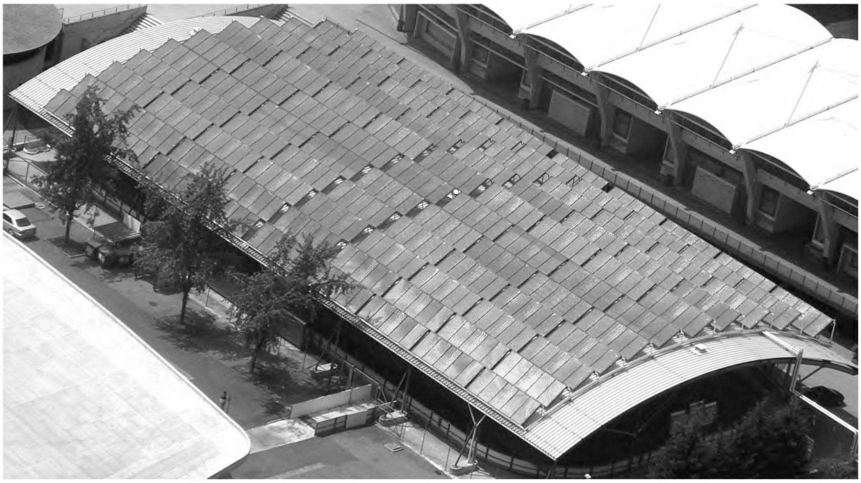
The "Berliner Ring" is a residential area with 27 multi-storey buildings comprising 756 apartments. Before the installation of the solar system, hot water preparation and heating were entirely done by fuel oil. The total consumption amounted to about 1 million litres of light fuel oil per year. Six separate solar plants were installed to feed a central storage tank that supplies water for heating. The system is designed to cover most of the summer demand for hot water.

Solar thermal systems use free fuel from the Sun (solar radiation) to heat water. This hot water is used to provide space heating or cooling, domestic hot water and process heat.

3.3 UPC-Arena Graz – Solar district heating

Collector Field: 1407 m^2
Storage: 0 m^3
Yield/Year: 520 MWh/year
Commissioning: 2002

The solar plant, mounted on the roof of the Skating Hall at the UPC-Arena, which is Graz's main soccer stadium, supplies heat directly to the municipal district heating net. More than 500 households get solar energy through the net without requiring the mounting of panels on their own roofs.



4 International Reference Plants of S.O.L.I.D GmbH

4.1 Olympic Village (Qingdao, China)

Collector Field: 666 + 631 m^2
Storage: 20 m^3 totally
Heating Load: 600 kW
Cooling Load: 500 kW
Commissioning: 2006

Two installations supply the Olympic sailing village in Qingdao. One is designed to supply sanitary hot water to the Olympic village and heat the swimming pools. The solar collector panels are integrated into the shaped roof of the training centre in a way that makes a dramatic architectural statement. The other installation is cooling and heating the logistic centre that includes a restaurant, shops, and office facilities.

4.2 "DESERT OUTDOOR CENTER" (ARIZONA, USA)

Collector Field: 126 m²
Storage: 4 m³
Cooling Load: 70 kW
Commissioning: 2006

The first cooling system in the USA was recently installed approx. 60 km north of Phoenix, Arizona. The solar cooling system was designed with a base-load capacity of 20 tons – 70 kW. It was installed using a prefabricated energy cabin including all major technical units like pumps, control and solar refrigeration unit.

4.3 HOSPITAL IN OSTRAVA (CZECH REPUBLIC)

Collector Field: 441 m²
Storage: 18 m³
Commissioning: 2003

This solar plant in Ostrava is supplying a children's hospital with hot water throughout the year. Generally, hospitals are huge consumers of hot water and are very attractive applications for solar energy.

Solnet – First Structured International PhD-courses on Solar Heating and Cooling

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Introduction

The European Union supports a PhD-network on 'Advanced Solar Heating and Cooling for Buildings' (Solnet) since June 2006 over a period of four years. The network consists of nine university research groups from seven different European countries and several commercial enterprises, working in the fields of civil, mechanical, and environmental engineering. The program is coordinated by Kassel University, Germany. Eight students received a three-year PhD scholarship and started their PhD project at the end of 2006 in the framework of Solnet. Two more students will join the network by June 2007. The common scope of the research activities is to contribute to new developments of solar heating and cooling systems with high solar fraction and for new applications. Bi-annually, PhD courses will be offered by the network participating universities, covering topics closely related to the research projects.

Training Activities

The aims of the training activities are to bring together European expert knowledge and education experience in solar thermal engineering. Seven bi-annual courses will be offered to the network students to different topics, e.g. about solar collectors, storages, solar cooling etc. New education modules on PhD-level will be developed. Other PhD students and university teachers working in the field are cordially welcome to join the courses. The participation is free of charge.
The participating institutes of the consortium are listed in Table 1.

Research Activities

The common target of the research projects is to develop and investigate solar heating and combined solar heating and cooling systems as well as the necessary components that pave the way for covering a greater fraction of the total heating and cooling load. Experimental and computational studies are carried out on systems, components and applications. For example, solar heating systems for the northern and central European region are investigated, as well as their interaction with CO_2-neutral back-up systems like pellets and wood burners. Another focus is on cooling- and de-humidification of office buildings and houses for southern European climate.

In annual plenary network meetings, supervisors as well as PhD students and external experts will evaluate results of the ongoing research and the network activities.

Collaboration between the participating research groups is based on exchange of students, modelling tools and common boundary conditions. The research topics for the individual PhD projects are listed in Table 2. They are in line with the priorities within the field of solar thermal as defined by the EUREC agency.

University	Department	Country
Högskolan Dalarna	Solar Energy Research Center	SE
Lund University	Dpt. of Construction and Architecture	SE
Technical University of Denmark	Dpt. of Civil Engineering	DK
Kassel University	Inst. of Thermal Engineering	DE
Czech Technical University	Dpt. of Environmental Engineering	CZ
Univ. of Applied Science Stuttgart	Dpt. of Building Eng. and Building Physics	DE
Graz Technical University	Inst. of Thermal Engineering	AT
Politecnico di Milano	Dpt. of Energetic	IT
Lleida University	Dpt. of Engineering and Environm. Science	ES

Table 1: Participating universities in the Solnet consortium.

The *research topics* cover:

- system components (e.g., advanced collectors, stores, cooling cycles),
- system integration aspects (interaction of the solar thermal system with an auxiliary energy supply system and the different heat consumers),
- new materials (e.g., phase change materials),
- new applications (air-conditioning, solar sorption cooling), and
- numerical system modelling (system investigations, mathematical optimisation).

Course Program

The overall research training project is monitored during project meetings taking place in the framework of the bi-annual course modules, with student presentations, forums, and project discussions. The courses cover system components, innovative materials, system evaluations and optimisation strategies, the overall energy situation in Europe, societal issues and they convey complementary skills. The preliminary course schedule is shown in Table 3.

	Location	Subject
1.	Borlänge (SE)	Investigations of solar and pellet heating systems
2.	Lund (SE)	Radiation balanced solar collectors for high solar fraction for electrically heated houses
3.	Kgs. Lyngby (DK)	Design of solar combi systems
4.	Kassel (DE)	Mathematical optimisation of the planning of solar heating systems.
		Components of a solar cooling system using liquid desiccants
5.	Prague (CZ)	Building integrated solar thermal collectors for SHC
6.	Stuttgart (DE)	Research on solar heating and cooling for building
7.	Graz (AT)	Applications of heat storages with Phase Change Materials (PCM) in solar energy systems
8.	Milan (IT)	Development and optimisation of a novel desiccant and evaporative system for solar air conditioning
9.	Lleida (ES)	PV- thermal generator optimised for solar heating and cooling applications

Table 2: PhD topics in Solnet.

Contact

Interested early stage researchers are cordially invited to join the network by participating in the Solnet courses. Applications are necessary. Application forms can be downloaded from www.solar.uni-kassel.de/solnet

Conclusion

With the Early Stage Research Training Project 'SolNet' in the framework of the Marie-Curie Programme of the European Union, the number of PhD students active in the solar field could be increased significantly. Within SolNet, ten PhD students have the opportunity to carry out their research projects at different institutes in parallel. A 'critical mass' could be reached to make it possible for the participating Universities to offer bi-annual courses on a high theoretical level. The first two courses that took place so far, were evaluated very positively, not only by the SolNet students, but also by a high number of additional PhD students who attended the courses. A high degree of cooperation and networking is expected for the following three years.

Acknowledgement

The authors would like to thank the advisory committee, represented by Professor Anne Grete Hestness, Trondheim, Norway, Professor Dr. Sigrid Jannsen, Freiburg, Germany, and Dr. Despina Serghides, Cyprus, for their support of the Solnet network.

Course Module	Date	Host	Main topic	Secondary topic
M1	Jan. 22-31, 2007	SERC Sweden	Dynamic System simulations using TRNSYS and other simulation programs: Development of network program & joint subsystems	Social-anthropologica l aspects
M2	Mar.26 - Apr.3, 2007	TUGraz Austria	System integration of solar thermal plants: Components, guidelines, characterization, analysis of applications, hydraulics, control systems, dimensioning and optimisation, design exercise and an excursion to built examples.	Presentation skills, Computational Thermal Engineering
M3	Oct. 10-17, 2007	DTU Denmark	Thermal stratification in solar heat storage tanks: Importance, establishment, maintenance, modelling, experimental investigations	Particle Image Velocimetry
M4	Mar. 5-11, 2008	HfT / POLIMI Italy	Solar cooling: Cooling load calculations, impact on system design, on thermodynamics and planning issues of open sorption, absorption and adsorption cooling systems	International standards and norms (SWT-Stuttgart)
M5	~ 10/08	CTU / Uni-Lund Sweden	Advanced solar collectors: Flat plate & concentrating, liquid & air collectors, optical properties, selective coatings, non-tracking systems, dynamic characterization, integration into the building envelope, hybrid solar air-water and PV-thermal collectors, solar walls, numerical models	Climate Policies, Project Management
M6	~ 03/09	Uni-Lleida Spain	Design and simulation of PCM (phase change material) applications to low energy-buildings: Material properties, heat transfer analysis, micro- and macro encapsulation of PCMs, passive and active applications, TRNSYS modelling	Differential Scanning Calorimetry
M7	~ 10/09	Uni-Kassel Germany	Renewable energy and energy efficiency: Technologies, energy economics, global environmental situation, resources, energy transformation, rational energy utilization, and electrification in rural areas	Energy economics

Table 3: Course schedule: Modules M1-M7.

Solar thermal legislation on municipal, regional and national level in Spain. Success and remaining barriers

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Introduction

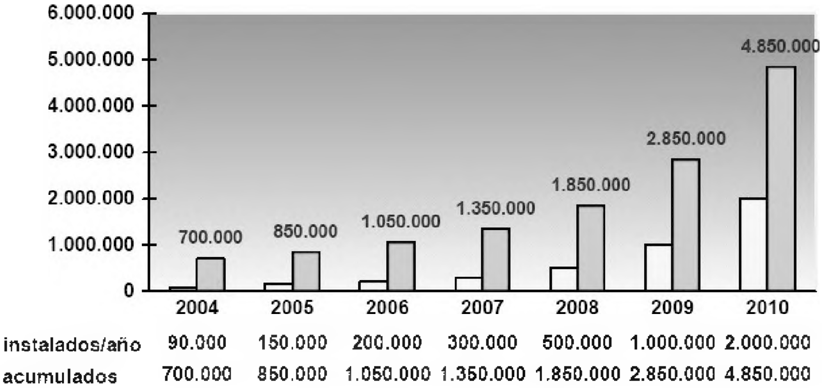
The solar thermal ordinance adopted by Barcelona City Council in August 1999 was the first in Spain. It made the installation of solar thermal energy systems mandatory for most new buildings and those undergoing major renovation. Since then, so many Catalan municipalities have followed this very successful example that by the end of 2005, already more than 50% of the region's citizens lived in municipalities with a solar thermal legislation. In parallel, the "Barcelona model" was adopted by other cities as Madrid or Seville. In February 2006, the Catalan Government adopted the so called Decree on Eco-efficiency, obliging all new buildings to install solar thermal energy systems. The Spanish transposition of the European Building Performance Directive (2002/91/EC), in force since September 2006, also includes the compulsory installation of solar thermal energy systems in new buildings.

Success of solar thermal legislation

The local initiative of Barcelona City Council making installation of solar thermal systems compulsory in new buildings resulted in extraordinary growth during the first years following introduction. Market penetration increased from 1.1 m^2/1,000 inhabitants in summer 2000 to 20.7 m^2/1,000 inhabitants in December 2005, roughly equivalent to a 2000% increase in just over five years, and nearly reaching the European average of installed collector area per capita. Concerning the distribution among the different building sectors, it can be stated that approximately 60% are residential blocks, 20% are hotels and 10% are sports facilities. Similar developments took place in lots of other Spanish municipalities that followed the "Barcelona Model". This success encouraged Barcelona City Council to revise the Ordinance in 2006 enlarging the number of construction types affected by the ordinance, so that – like in the national and regional building regulations – all new buildings must now comply with this legislation.

Ambitious objectives and market potential

Concerning the development of the solar thermal energy sector in the coming years and its contribution to increase the share of renewable energies in the overall energy consumption, both the Spanish as the Catalan Government have fixed ambitious objectives. The national target is of nearly 5,000,000 m² installed collector area in 2010, equal to far more than 50% annual growth for the coming years.



Graph 1: Solar thermal market development in Spain 2005–2010; Source: ASIT

Based on the existing legislation on the three mentioned levels – national, regional and local – and specific support activities, only for Catalonia, the regional governmental target foresees growth from the existing 90,000 m² installed collector area at the end of 2005 to 1.25 million m² in the year 2015, mainly in the residential sector.

Although the development of the last ten years is not expected to continue at such a high rate, the building sector has been the motor of the Catalan and Spanish economy for many years. By way of example, 812,000 new apartments were built just in 2005. Taking into account the mandatory installation of solar thermal energy systems in any new building and the increasing need for refurbishment in the housing sector, if the sector is able to meet the huge demand, the growth potential of the solar thermal energy market described above may even prove to be an underestimation.

Regional strategies/support to overcome remaining barriers

However, there are still important barriers to overcome which may slow down this possible take-off. These include continuing general lack of information concerning solar thermal energy systems among the actors of the building sector and the general public. Furthermore, although there is increasing interest among conventional installers and plumbers in acquiring knowledge on solar thermal, trained craftsmanship and especially those with experience in monitoring and maintenance programmes to guarantee the thermal energy yields over the lifetime of the installation are still rare. At the administrative level, although a huge number of municipalities now have a solar thermal ordinance, the integration of the installations as an architectural element is still unusual and quite often parallel building ordinances oblige the installation to be located out of sight from the street so as not to disturb the visual perception of the overall urban landscape. Finally, the existing national procedure to certify the quality of solar thermal equipment – a compulsory requirement to receive public subsidies for installing a solar thermal system – does not facilitate either the introduction of foreign companies into the Spanish market or the commercialization of new national product developments.

With the aim of overcoming or at least significantly reducing some of these barriers, the Catalan Energy Institute (ICAEN) has undertaken a huge number of different activities in recent years, from general awareness building campaigns to specific support lines for research and development of new solar thermal applications. In order to improve the quality of the installations, special training material and programmes for installers have been designed and used in fact-to-face and on-line courses offered in collaboration with professional associations of the sector. To strengthen the municipal level, two years before the approval of the new building code (CTE), a solar ordinances support centre was created to help identifying possible difficulties in the implementation of existing local solar ordinances and to promote the development and adoption of new ones. Another very successful initiative is the Solar Schools Network that, at the end of 2006, included more than 100 educational centres with a total solar thermal collector area of 1,500 m² and several hundred kW_p fotovoltaics, monitored and with real-time published energy yields available via internet.

Another important fact to mention is the economic support to solar thermal energy systems by annual subsidy schemes, despite the mandatory introduction in the frame of the new Spanish Building Code CTE. In this sense, in 2006, nearly half of the overall budget of 5,000,000 € subsidies for renewable energy systems was allocated to solar thermal projects. The maximum subsidy was fixed at 37% of the investment costs, equivalent to approximately 260 € to 300 €/m² collector area, but innovative projects as solar cooling, solar thermal for process heat in industry or the promotion of Energy Service Companies (ESCOs) selling solar heat were eligible for substantially higher subsidies in order to facilitate the market introduction of these technologies or business models.

The demonstration project "CAP Roger de Flor"

Another important activity of the Catalan Government to promote solar thermal energy consists in giving maximum publicity to systems installed in public buildings, such as hospitals, schools, community centres or administrative buildings. A perfect example for this policy is the new built health centre "CAP Roger de Flor" in the city centre of Barcelona, which is one of seven demonstration buildings for energy efficient building design in the frame of the European Commission co-financed project SARA ("Sustainable Architecture Applied to Replicable Public Access Buildings" – contract n° 503694), under the leadership of Universitat de Barcelona, aiming at cost effective, high energy performance, public-access eco-buildings.

The centre was designed with a holistic approach concerning the reduction of the overall energy consumption, taking into account the embodied energy of construction materials as well as the energy demand during the use of the building. In this sense, the building's envelope is highly insulated avoiding thermal bridges, well shaded, and includes a central patio to increase natural ventilation and day lighting of the interior spaces. An innovative cooling and heating system designed around radiant ceiling panels and a dehumidification system based on lithium chloride should reduce energy consumption for space heating and cooling by about 25%.

24 m² of unglazed solar collectors AS (Energie Solaire SA) on the roof top are installed to meet at least 60% of the demand for heating domestic water. The monitoring and building management system (BMS) allows the solar thermal energy yields and contribution to the domestic water heating to be controlled, monitored and visualised graphically in real-time. This information will be available on the project's web-site: www.sara-project.net and also used in training and education activities. With the experience from the Solar School's Network, the online availability of real data has shown an increased interest in renewable energy technologies and is considered a useful tool for raising awareness. Information on the project and the performance of the renewable energy systems will be also projected on the large-size screen installed in the entrance of the centre to attract public attention.

Conclusion

Solar thermal legislation has been shown to be an excellent tool for pushing a take-off of this renewable energy technology in the market at local, regional and national level in Spain. Nevertheless, a number of accompanying measures, from dissemination activities to specialized training of professionals, are necessary to build awareness and ensure the quality of the installations.

Quality assurance with the ISFH-Input/Output-Procedure 6-year-experience with 14 solar thermal systems

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Introduction

The operators of standard solar thermal systems usually don't recognise failures affecting the solar yield, because an auxiliary heater supplies the consumers with warm water even in the case of failures. In order to assure the operator that the solar system is working properly over its lifetime, a procedure for controlling the solar heat has been developed at ISFH since Dec. 1999 and tested in 14 different solar thermal systems. Our motivation is to help removing the reluctance of investors of medium solar thermal systems by increasing the confidence in solar thermal energy.

The so called Input/Output-Procedure is controlling the solar heat by an automatic comparison of measured and expected collector yields on a daily basis. The expected collector yield is calculated with a simplified simulation model.

Because the Input/Output-Algorithm is very compact, it can be integrated into standard control units, so that low-cost-devices are realisable. Prototypes of I/O-Controllers (IOC) with an implemented algorithm have been installed in 14 different solar systems. The simulation model was validated with measured data and a lot of failures in 11 solar thermal systems could be detected in the past six years.

In a sensitivity analysis that takes into account both the uncertainties of the parameters as well of those of the measurements, the over-all uncertainty of the procedure has been determined to about 7%.

The ISFH-Input/Output-Procedure

General specifications

For the daily comparison of measured and expected collector yields, the I/O-Controller has to measure the heat output as well as the input quantities of the simulation model for the calculation of the expected out-put.

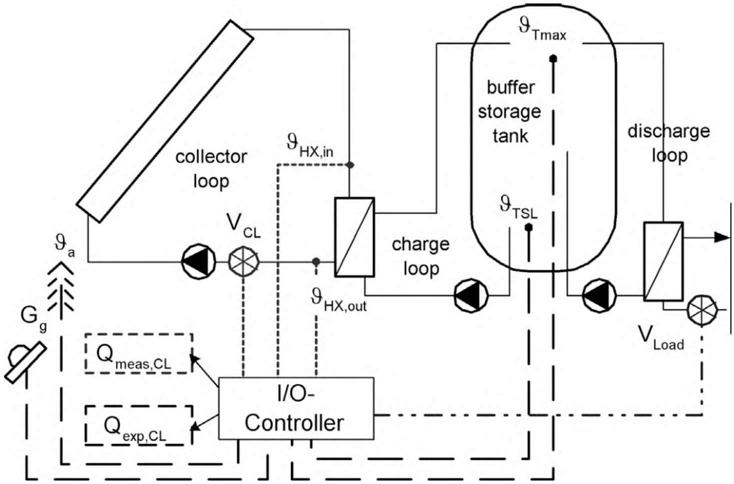

Fig. 1: Schematic diagram of the integration of an Input/Output-Controller and associated sensors into a solar system with buffer storage tank and direct discharging.

Fig. 1 shows the sensors which are typically required for the Input/Output-Procedure. Optional sensors may be installed for more information or in order to facilitate trouble-shooting in case of a failure.

For the measurement of the yield of the collector loop $Q_{meas,CL}$ the volume flow rate V_{CL} and the temperature difference between inlet and outlet of the heat exchanger ($\vartheta_{HX,in} - \vartheta_{HX,out}$) are required. The expected yield $Q_{exp,CL}$ is simulated with measured data of irradiance G_g, ambient air temperature ϑ_a, typical solar load temperature ϑ_{TSL} and the high-limit cut-off temperature ϑ_{Tmax}. Furthermore the I/O-Controller has to know up to 40 parameters of the solar system (e.g. collector efficiency coefficients like zero loss coefficient and heat loss coefficients, tilt, collector area).

The ϑ_{TSL} describes the temperature of the heat sink of the collector loop, which can be a (buffer) storage tank, a return pipe of a district heating system etc. The main advantage of using the ϑ_{TSL} is that the same mathematical model can be taken for the collector loop of all kinds of systems.

The Input/Output-Algorithm

The structure of the IOC-Algorithm is shown in Fig. 2. At first, the logged measured data as well as the parameters are checked for plausibility within the IOC-Algorithm. Then, on the one hand, the measured yield is calculated and, on the other hand, the expected yield is simulated by solving a mathematical model of the collector loop.

The irradiation processor is dividing the global irradiance into diffuse and direct radiation and calculates its incidence angle.

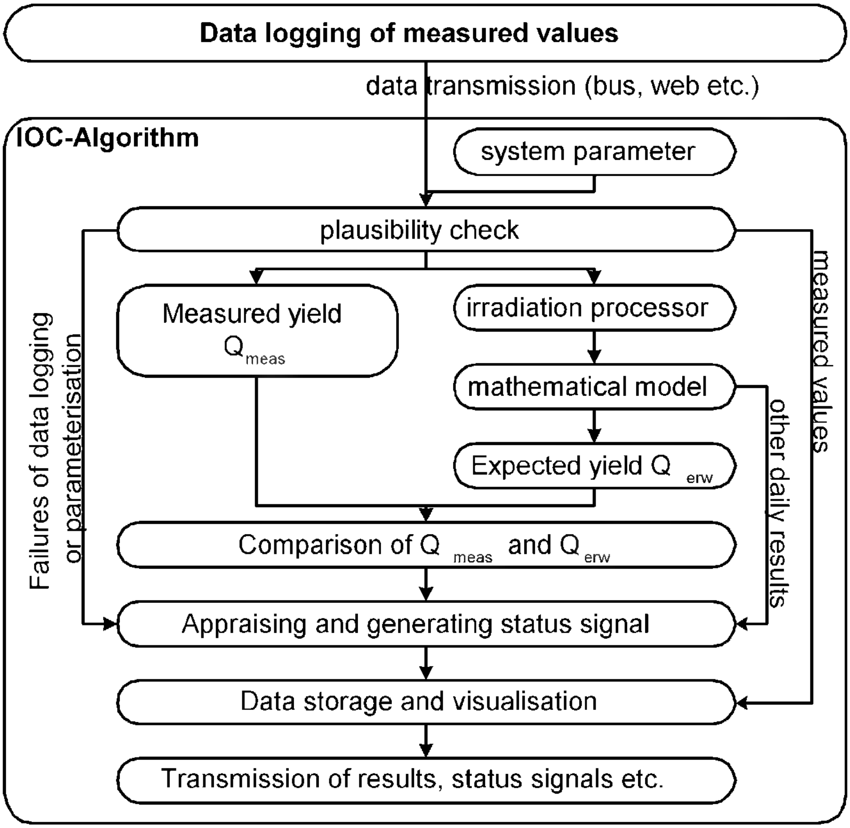

Fig. 2: Structure of the Input/Output-Algorithm that can be integrated into standard control-units or servers.

At the end of the day, the deviation between the two values Q_{meas} and Q_{exp} is determined automatically. Together with additional information of the plausibility check and other results of the simulation, the generated status signal specifies as accurate as possible the cause of the failure. In order to facilitate trouble-shooting, measured data as well as simulation results are stored.

The measured and expected daily outputs of the collector loop can be plotted vs. the daily irradiation (input) in an Input/Output-Diagram (q. v. Fig. 3). Solar domestic hot water systems show a well-known linear relationship, but also solar systems for space heating that do not show such a linear population can be controlled with an Input/Output-Controller, because of the dynamic simulation of the expected output.

Failures in the collector loop can be seen easily in an Input/Output-Diagram, because the measured values strongly deviate from the expected values.

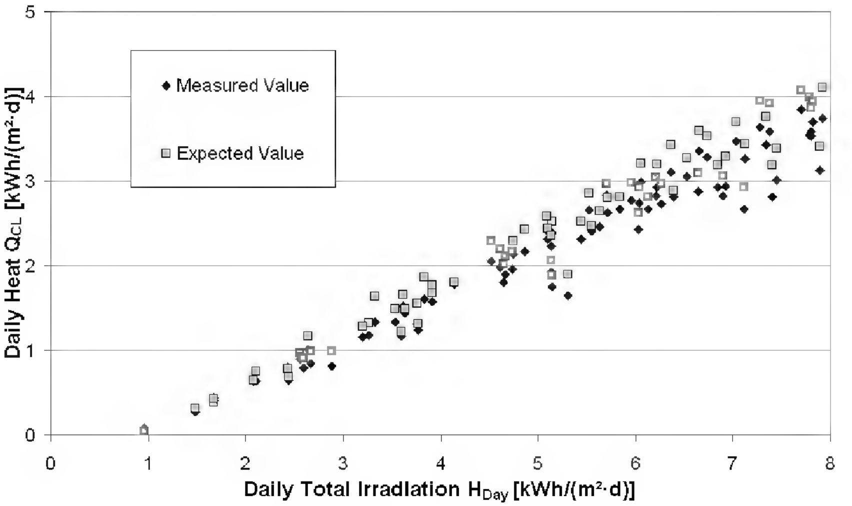

Fig. 3: Input/Out-put-Diagram of an attended solar sys-tem of a hospital in Solingen (192 m²) from 2003. The failure occurred in the collector loop. The measured yields of the collector loop strongly deviate from the expected yields (encircled measured values).

The volume flow rate of the load V_{Load} (warm water consumption) and the storage temperature at the relevant position for the high-limit cut-off ϑ_{Tmax} (q. v. Fig. 1) are important information for the algorithm to distinguish a failure in the discharge loop from the effects of lacking heat demand, so that discharging failures can be detected.

In case of low heat demand, e.g. in holidays or in summer periods for solar combi-systems, no significant difference between measured and expected values results. This is important to avoid false signals that confuse the operator, because this is a normal state of solar systems.

Mathematical model

One goal for the development of the mathematical model for the collector loop was that it should be applicable for the implementation into standard control units. For that reason the heat demand V_{Load} is not an input for the model as it is for typical simulation programs. Instead the input quantity for the model is the typical solar load temperature ϑ_{TSL}. By using the ϑ_{TSL} the following advantages were achieved:

- Applicability for various solar system-types without adaptation of the algorithm
- Differential equation is solvable analytically, accurate enough and can be integrated into standard control units

→ Possibility for implementation into small inexpensive I/O-Controllers!

Sensitivity analysis

For the interpretation of the deviation between measured and expected collector yield (Q_{meas} and Q_{exp}) the uncertainty of the Input/Output-Procedure has to be known. The uncertainty of the Input/Output-Procedure depends on the uncertainties of parameters, measured values and simplifications of the simulation.

Comparisons of validation studies against measured data using Input/Output- and TRNSYS-results showed similar accuracy patterns for both simulation methods.

The joint influence of the uncertainties of parameters and measurement on the uncertainty of the I/O-Procedure was analysed in a sensitivity analysis. This is done in three steps:

- At first, the uncertainties of the parameters as well as the measured values have to be assumed conservatively.
- Next, the original values of the parameters and the measured data were modified with their standard uncertainty in order to calculate their effect on the collector output. This was done with data of one year of a typical solar system.
- At last, all the individual uncertainties have to be added as root sum of squares because they do not occur in the same direction.

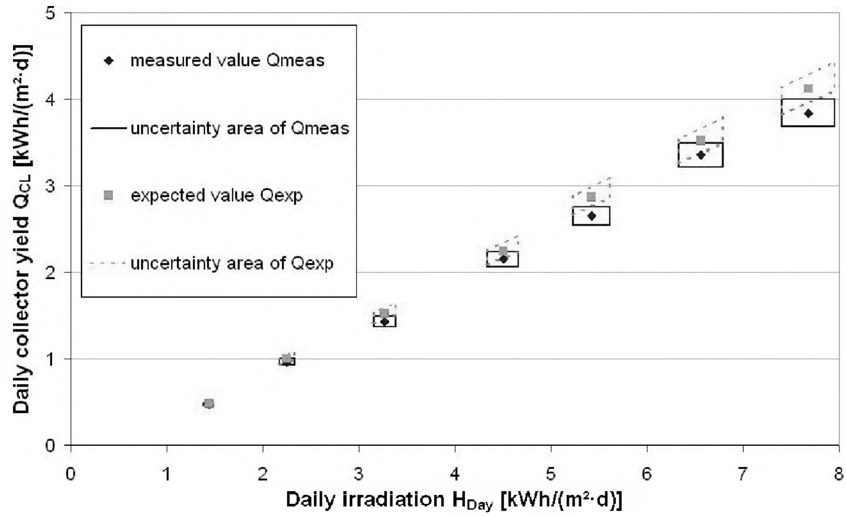

Fig. 4: Schematic diagram of the uncertainty areas of Q_{meas} and Q_{exp} as well as the suggested tolerance area.

The mean uncertainty *of the expected yield* of the collector loop results to 5.2%, while the uncertainty *of the measured yield* of the collector loop is approx. 4% (q. v. Fig. 4). Taking both effects into account, the standard uncertainty of the Input/Output-Procedure follows to about 7%. Our suggestion is to fix a triple standard uncertainty as tolerance limit. Thus, a fault can be detected with a probability of 99% if a difference between measured and simulated yield of 20% is exceeded. Because of increasing uncertainties of the simulation for low irradiation values, the tolerance is modified to an absolute value of 0.3 kWh/(m^2·d) for expected yields below 1.5 kWh/(m^2 · d).

Conclusions

- The ISFH-Input/Output-Procedure provides automatic in situ controlling of the measured collector loop yield by comparing it with a simulated value.
- The dynamic simulation algorithm to calculate the expected yield can be integrated into standard control units because the mathematical model is simple and analytically solvable. This enables low-cost Input/Output-Controllers.
- The mathematical model has been validated against measured data of 19 different solar systems. The average deviation is under 10% which exceeded our expectations. The model is applicable for various solar systems without adaptation of the algorithm.
- The uncertainty of the I/O-Procedure concerning the uncertainties of parameters and measured data is about 7%. If the limit of tolerance between measured and simulated yield of e.g. 20% is exceeded a fault is existent with a probability of 99%.
- The first licence is given to RESOL® that will offer I/O-Controllers on the Intersolar2007. Other interested parties are welcome.

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SaTherm: Satellite-based Monitoring of Solar Thermal Systems

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INTRODUCTION

Low-temperature solar thermal systems for hot water and space heating applications are widely appreciated as reliable and efficient renewable energy technologies. However, an examination of commercially available solar combi-systems at the Swiss Institut für Solartechnik SPF showed that "only few systems are installed properly and work fine from the beginning" [1]. It is therefore not impossible that several months could pass by before under-performance or even defects might be noticed. Performance monitoring might therefore come-in handy for system suppliers, installers as well as owners, provided a simple low-cost solution would become available. Satellite-based monitoring might provide a solution herefore.

GOAL OF THE PROJECT

The authors of this paper consider developing a reliable and cost-effective monitoring service for low-temperature solar thermal systems. This service shall be applicable for solar thermal systems of any size, any system provider and any location. Since costs for such a service should not exceed a few Euros per year, no additional sensors and measurement equipment should be needed.

Additionally, alarms and monitoring results should be directly available to the installer or a services company. Local alarms are impractical, where as state-of-the-art visualisation of monitoring data on a password protected homepage appears attractive. This would allow authorized persons easy access via internet to the past and present data of monitored systems. Remote diagnostics accelerate the response time in case of a malfunction and reduce the number of site visits.

A key factor of the planned monitoring service is the integration of meteorological data from weather stations and satellite pictures. Mainly irradiance and snowfall information shall be taken from satellite pictures and used to interpret the measured operating data of the solar thermal systems. Thanks to the inclusion of such meteorological data, trend analyses of the system behaviour would be possible without the need for any local irradiance measurement.

Principle of operation

As depicted in Fig. 1, the suggested monitoring approach appears to be simple: The solar thermal controller registers hourly values of temperature, pump status and yield of the solar system and transmits these values daily via email to a central server. The maximum possible yield of the solar thermal system could be calculated by using common characteristics of the system and irradiance data derived from satellite pictures. Failure detection software daily could compare the measured values with the maximum possible, calculated yield on a daily basis and, if needed, could search for malfunction or defects in the solar thermal system. In case of such malfunction, the operator could be informed via email or SMS. Measured values, the maximum possible yield and the results of the analysis would be saved on the central server and therefore become permanently accessible via internet platform.

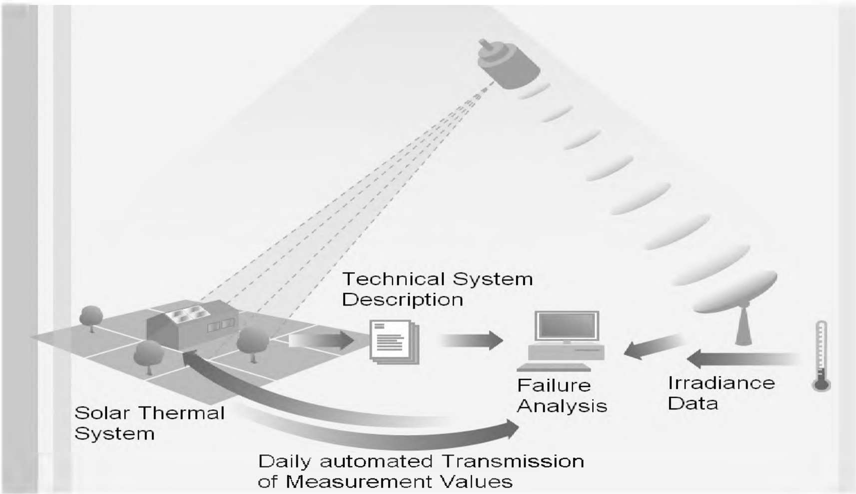

Fig. 1: SaTherm's principle of operation

Data measurement and transmission

To minimise costs for hardware, installation as well as service, data measurement and transmission should be integrated into the standard controller of the solar thermal system. Any necessary additional specifications for the controller would be rather minimal, including temperatures of collector outlet as well as of the storage vessel and the working status of the solar loop circulation pump. Such data should be measured regularly and sent via email to a central server.

Automated analysis with the aid of satellite data

Whereas the actual performance of the solar thermal system could be calculated on the basis of registered and transmitted system status data, the use of satellite pictures and additional meteorological data sources would allow comparing this data with the calculated maximum possible energy yield of the system. Fig. 2 illustrates such possible comparative performance information.

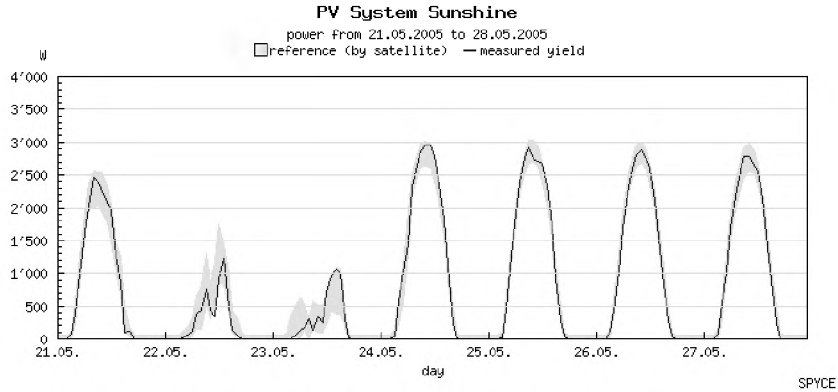

Fig. 2: Visualisation of the maximum possible yield (shaded area) and the actually produced yield (dark line) of a photovoltaic system. Similar graphs are envisaged to be derived for solar thermal systems, too.

Failure detection routine and alarms

The energy yield of the system would be automatically compared with the maximum possible energy yield. Additional measurement data (e.g. pump status or alarms from the controller) and additional meteorological data (e.g. snowfall or snow coverage information) could be included. An automated routine could investigate this data every night and search for plausible technical defects. If the routine detects an unambiguous malfunction or defect, an automatic alarm email would be sent to the service authority of the solar thermal system.

Visualisation of data in web-portal

A password protected web-portal could make all measurement data of the solar thermal system accessible at any time for authorised persons. There could be several levels of access. End users might have restricted access with easy to understand production graphs. Professionals (e.g. installers) could be able to see all data and to enter, edit and delete descriptions of solar thermal systems. They could also add customers and give them restricted access to the web-portal. Companies (e.g. manufacturers of solar thermal controllers) could establish their own web-based monitoring portal. In this case, the layout and design of the web-portal would be adapted to the corporate identity of the company.

Conclusion

An online monitoring service could lead to faster detection of malfunctions or defects and thus reduce the performance of solar thermal systems. Because of all measurement data becoming permanently accessible via internet, identification of defects is easier and expensive local analyses could be avoided. The automated alarms via email would further minimise operational expenses. Thanks to satellite images also irradiance and snow data could be included in the analysis automatically. This would facilitate the identification of defects and help to prevent false alarms. The service is targeted to cost only a few Euro/year/system and thus be cost effective. Because neither additional hardware (no additional sensors should be needed and the data logger would already be integrated within the controller of the solar thermal) nor software would be needed, the system could be robust and easy to install.

The co-authors Enecolo AG and Meteotest already developed a similar web-based monitoring service for photovoltaic systems (www.spyce.ch) [2]. These companies are planning to set up the monitoring service for solar thermal systems including data handling, internet portal and all routines for automated data analysis. It is suggested that such a project be scientifically supported by the Swiss Institut für Solartechnik SPF.

It is hoped that the online monitoring of solar thermal systems would become a standard. At the moment, visualisation of the measurement data on a password-protected homepage could already be offered to interested companies. The project partners are looking for partners to develop and implement such as promising satellite-based monitoring system.

References

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Simple method for the calculation of a performance figure for solar thermal collectors

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Introduction

The Solar Keymark for collectors which has been established in the year 2003 has become a huge success by now. By the end of the year 2006 already 140 different collector types did carry the Solar Keymark label. Many countries already base their subsidy schemes on Solar Keymark certification and other European countries are planning to do so. However, to strengthen the Solar Keymark even more and to establish the mark as THE unique criteria for subsidies, a method for the determination of the collector performance has to be integrated in the certification scheme. This method should be suited to be the basis for the definition of a performance criterion.

In general the thermal performance of solar collectors is determined by dynamic system simulations based on the collector efficiency parameters derived from the physical test of the collector. Such methods are already successfully used in several European countries. However since the solar thermal systems in Europe are quite different from country to country it will be very difficult to find one system configuration that will be accepted all over Europe. Furthermore the simulation tools are not easy to use and transparent for everybody.

This paper presents a simple calculation method to determine a performance figure for solar thermal collectors which can be used as basis for a possible performance criterion that can be incorporated within the Solar Keymark certification scheme rules.

The basis for the calculation method is the power curve of the collector according to EN 12976:2006 chapter 6, which is described by the conversion factor η_0 and the heat loss coefficients a_1 and a_2. In order to account for incident angle effects, both the incident angle modifier for beam irradiance as well as the incident angle modifier for diffuse irradiance are included. Finally to consider the transient behaviour of the collector the effective heat capacity of the collector is also included into the method.

As result of the calculation a dimensionless collector performance figure (CPF) in the range between 0 and 1 is determined. This collector performance figure is suited to be the basis of a performance criteria that can be incorporated in a future version of the Solar Keymark scheme rules e.g. in order to decide if a collector will or will not benefit from subsidies.

Approach

In order to design a performance figure for solar thermal collectors which will be accepted well throughout Europe three major criteria were considered:

1. the method must include all mandatory collector parameters according to EN 12975-2:2006
2. the method must be simple to use
3. the method must reflect, to a reasonable extent, the results of a detailed system simulation

The collector performance figure

The collector performance figure (CPF) (eq. 1) is based on the integration of the power curve f_{pc} (eq. 2) corrected by the factor f_{IAM} (eq. 3) representing the impact of the incidence angle modifier and the factor f_{Ceff} (eq. 4) taking into account the effect of the effective heat capacity of the collector.

$$CPF = f_{pc} \cdot f_{IAM} \cdot f_{Ceff} \tag{1}$$

$$f_{pc} = \frac{\int_{\Delta T=0}^{100} AG\left(\eta_0 - a_1\frac{\Delta T}{G} - a_2\frac{(\Delta T)^2}{G}\right)d\Delta T}{\int_{\Delta T=0}^{100} AG d\Delta T} \tag{2}$$

$$f_{IAM} = 0.85\overline{K}_b(\theta) + 0.15K_{dfu} \tag{3}$$

$$f_{Ceff} = 1 - 0.03\ln C_{eff} \tag{4}$$

The power curve is integrated within the range of $\Delta T = (\vartheta_{fl,m} - \vartheta_{amb})$ from 0 to 100 K where a global irradiance of G = 1000 W/m² is used. In order to achieve a dimensionless and area independent collector performance figure (CPF) the integral is divided by the integral of the solar radiation available for the collector within the same boundaries of integration.

The factor f_{IAM} takes into account the mean value of the incidence angle modifier for the beam irradiance $\overline{K}_b(\theta)$ in the range of θ = 0 to 70° as well as the incidence angle modifier for diffuse irradiance K_{dfu}. In compliance with EN 12975-2:2006 a diffuse fraction of 15% is chosen.

The impact of the transient behaviour of the solar collector is described by an empirical approach using the natural logarithm of the effective heat capacity of the collector, taking into account the decreasing collector performance with increasing effective heat capacity. The approach is valid for effective heat capacities between 1 and 60 kJ/(m²K).

Exemplary application of the collector performance figure

The exemplary application of the collector performance figure is shown in Table 1. Collector 1 is an ordinary flat plate collector and collector 2 an evacuated tubular collector (Sydney type) with a diffuse back reflector.

		Collector 1	Collector 2
A	[m²]	1.65	1.33
G	[W/m²]	1000	1000
η_0	[-]	0.737	0.695
a_1	[W/(m²K)]	3.817	1.357
a_2	[W/(m²K²)]	0.012	0.010
b_0	[-]	0.155	-
K_{dfu}	[-]	0.86	1.19
C_{eff}	[kJ/(m²K)]	11.28	44.03
$\overline{K}_b(\theta)$	[-]	0.92	1.19
f_{pc}	**[-]**	**0.506**	**0.594**
f_{IAM}	**[-]**	**0.913**	**1.193**
f_{Ceff}	**[-]**	**0.927**	**0.886**
CPF	**[-]**	**0.428**	**0.628**

Table 1: Exemplary application of the collector performance figure for a flat plate collector (collector 1) and an evacuated tubular collector (collector 2)

In case the incident angle modifier for diffuse irradiance has not been determined (test method under steady state conditions) a reference value of K_{dfu} = 0.84 should be used.

Validation with TRNSYS

In order to check if the proposed approach gives a reasonable ranking for different collectors TRNSYS simulations for five flat plate collectors and four evacuated tubular collectors were carried out under the so called "ITW reference conditions" (see Table 2).
In Fig. 1 the calculated collector performance figures are plotted over the simulated yearly collector gain for all 9 collectors. The comparison shows, within the limitations of a simplified method, a reasonable agreement

Conclusion and outlook

A simple method for the calculation of a collector performance figure (CPF) was introduced. The method uses all mandatory collector parameters according to EN 12975 and can easily be implemented in any spread sheet program. The suggested calculation reflects, within the limits of such a simplified approach, the collector performance determined using detailed system simulations. Thus it is suited to be the basis of a performance criterion that can be incorporated in a future version of the Solar Keymark scheme rules.

The suggested approach also leaves possibilities for the future. For example by multiplying the CPF with the yearly available radiation an approximation of the yearly energy gain of the collector can be calculated. Also a sharper differentiation between collectors for domestic hot water and space heating is possible if the boundaries of integration are chosen accordingly.

location:	Würzburg, Germany
roof orientation:	south; tilt angle equal to latitude
collector piping:	15 m each to store, from store; normal width DN 16; insulation thickness 25 mm, λ = 0,04 W/(mK), one half of each pipe is located outside, the other half is located inside
storage:	volume 300 l; heat loss rate 2.2 W/K; ambient temperatur 15 °C volume auxiliary 135 l; set temperature 60 °C stratification number 100; effective vertical heat conductivity 2 λ_{water}
heat:	immersed heat exchanger, heat transfer capacity rate $(UA)_{WT}$ in [W/K]; $(UA)_{WT} = 9 \cdot A_c \cdot \vartheta_m^{0,6}$ with Ac: apterure area [m²] ϑ_m: average value of heat exchanger inlet temperature and local storage temperature in [°C]
hot water consumption:	200 l/day ($7^{\underline{00}}$: 80 l; $12^{\underline{00}}$: 40 l; $19^{\underline{00}}$: 80 l); cold water temperature 10 °C; hot water temperature 45 °C annual consumption: 2936 kWh/a

Table 2: "ITW reference conditions" for the calculation of the yearly collector gain of a solar collector within a domestic hot water system

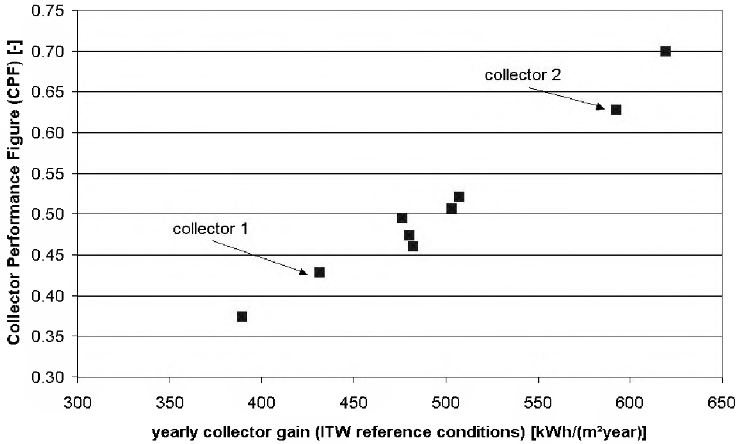

Fig. 1: Collector performance figure (CPF) versus the result of detailed TRNSYS simulation (for ITW reference conditions)

References

(1) EN 12975-2:2006: Thermal solar systems and components – Solar collectors –, Part 2: Test methods

Nomenclature

A	[m²]	Collector aperture area
C_{eff}	[kJ/(m²K)]	Area based heat capacity of the collector
CPF	[-]	Collector performance figure
G	[W/m²]	Global irradiance
η_0	[-]	Conversion factor
a_1	[W/(m²K)]	Heat loss coefficient
a_2	[W/(m²K²)]	Temperature dependent heat loss coefficient
b_0	[-]	Factor to determine the incident angle modifier of the beam irradiance
f_{pc}	[-]	Factor representing the impact of the power curve
f_{IAM}	[-]	Factor representing the impact of the incident angle modifier
f_{Ceff}	[-]	Facto representing tne impact of the effective heat capacity
$\overline{K}_b(\theta)$	[-]	Mean incident angle modifier of the beam solar irradiance
K_{dfu}	[-]	Incident angle modifier of the diffuse solar irradiance
λ	[W/(mK)]	Heat conductivity
ΔT	[K]	Temperature difference $\Delta T = (\vartheta_{fl,m} - \vartheta_{amb})$
ϑ_{amb}	[°C]	Ambient temperature
$\vartheta_{fl,m}$	[°C]	Mean fluid temperature
ϑ_m	[°C]	Average value of heat exchanger inlet temperature and local storage temperature
$(UA)_{WT}$	[W/K]	Heat transfer capacity rate

Efficiency testing of solar collectors and long term performance simulation tools: application to flat plate and CPC type collectors

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ABSTRACT

Simple superposition of collector efficiency curves measured according to standard procedures can not be quantitatively used to compare the performance of solar collectors of different types.

This paper compares two different collector types, a flat plate and a CPC, describing the essential aspects of their respective optical behaviour, in view of their energy performance evaluation.

It describes the importance of the proper incidence angle modifiers, in particular in the case of bi-directional collectors, like CPCs, and how to handle their bi-directionality in a proper way.

It also comments on the fact that collector parameters emerging from the standard efficiency curves, require a correction due to then fact that they are based on a radiation measurement on the collector plane (Icol) i.e. on radiation not yet "processed" by the optics of each collector type, while efficiency should be really referred to the quantity of radiation (Iabs) really absorbed by the absorber (i.e after the optics of each collector "processes" it). For flat plate collectors this is a small correction, but it is of a larger magnitude for concentrators, like CPCs. Recently, practical suggestions were put forward (Carvalho, M. J., 2007) to handle this matter and the present paper incorporates them in the analysis made.

Integrating all these effects the paper compares the performance calculated for a low concentration CPC and two flat plate collectors, a regular, non-selective one, and a very good selective one, at different constant operating temperatures, in two European locations, Freiburg (Germany) and Lisbon (Portugal).

I – INTRODUCTION

There are a growing number of solar thermal collector types: flat plates, evacuated tubes with and without backing reflectors and different tubular spacing, low concentration collectors, using different types of concentrating optics, in particular CPC collectors, also known as Ideal or Winston type concentrators. These different concepts and designs all compete to be more efficient or simply cheaper, easier to operate, etc. at ever higher temperatures, and even to extend the use of solar thermal energy in other applications beyond the most common water heating for domestic purposes.

This means that there is a growing need for the existing and future simulation tools to be as accurate as possible in the treatment of these different collector types, to allow for the proper dimensioning of solar thermal systems as well as the proper comparison of different collector technologies for a given application.

All the available tools use efficiency curves resulting from collector testing and these are based referred to the measurement of the available radiation (Icol) on the plane of the collectors, something that fits well the kind of optical behavior of flat plate collectors but which is too simple to handle concentrating ones. This also means that quantitatively comparing collectors from just looking at their respective efficiency curves, is really misleading.

Besides, unlike flat plate collectors, the other types referred, have a bi-directional behavior, as they handle the incoming radiation in a different way, i.e., they collect differently radiation in the longitudinal and in the transversal plane, or in any other plane in between. This is why existing standards require the measurement of the optical response of these bi-directional collectors in both orthogonal directions.

Several papers (McIntire, 1982 [1]; Rabl, 1985 [2]; Theunissen, 1985 [3]; Carvalho, 1987 [4]; Rönnelid, 1997 [5]) have dealt with this bi-directional problem, but a systematic approach merging together all the effects above, applicable to all collector types has recently been propose in two papers (Carvalho, 2007 [6,8]), just submitted for publication in SOLAR ENERGY.

This paper summarizes the ideas developed in the two papers referred above and applies them to the performance evaluation of two representative flat plate collectors (selective and non-selective) and one low concentration CPC collector, in two cities, Lisbon (Portugal) and Freiburg (Germany).

The paper is organized in the following way: in (II), a very brief description of the main optical characteristics of the collector types considered in the comparison is presented and condensed in their respective Incidence Angle Modifiers, in (III) a correction to the standard use of the values obtained from the efficiency curves is suggested in view of proper long term performance calculations, in (IV) long term performance calculations are shown at several constant operating temperatures and for two cities in Europe and in (V) a set of Conclusions is presented.

II – A brief comparison of optical characteristics of flat plate collectors and CPC collectors. Incidence Angle Modifiers and their use in performance calculations

Standard collector testing (EN 12975 [7]) determines the optical efficiency at normal incidence and (in the linear approximation) the heat loss coefficient. These quantities are usually described by the two quantities $F'\eta_0$ and $F'U_L$ or a_1. The efficiency η is defined by:

$$\eta = F'\eta_0 - F'U_L\,(T_f - T_a)/I_{col} \tag{1a}$$

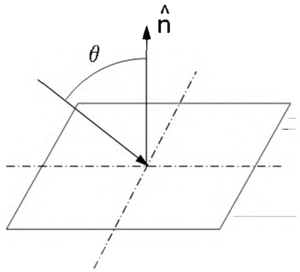
Icol is the incident solar radiation energy measured by a pyranometer on the collectors plane.

For flat plate collectors $F'\eta_0$ is given by (eq.1b)

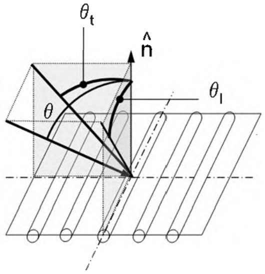
$$F'\eta_0 = F'\,\tau\,\alpha\,(\theta) \tag{1b}$$

where the product of glass transmissivity and absorber absorptivity ($\tau\alpha$) has a dependency on the incidence angle (θ) (see Fig. 1 (a)). Flat plate collectors do not exhibit a bi-directional behavior, unlike CPC collectors or evacuated tubular ones (Fig. 1 (b)).

$F'\eta_0$ is measured at normal incidence (i.e. $\theta = 0$) and the optical behavior of that product, for any other angle, is well described by the incidence angle modifier K (θ) defined by equation 2 (see also Fig. 2).



(a) Flat plate collectors



(b) CPCs collectors or evacuated tubular, bi-directional behavior

Fig. 1: dependency on the incidence angle (θ).

$$K(\theta) = \frac{\tau\alpha(\theta)}{\tau\alpha(0)} \tag{2}$$

A good functional form to describe the angular dependency of K(θ) is (Carvalho,1987 [4]; McIntire, 1982 [1], etc), and is generally used in all calculation tools.

$$K(\theta) = 1 + b_0\,(1/\cos(\theta) - 1)^c \qquad (3)$$

Where b_0 and c are constants determined by a least squares fit.

Fig. 2 shows K(θ) for the flat plate collectors considered in this paper. Standard tests measure K(θ = 50) and that is enough, with the knowledge that K(θ = 0) = 1, to determine the two constants.

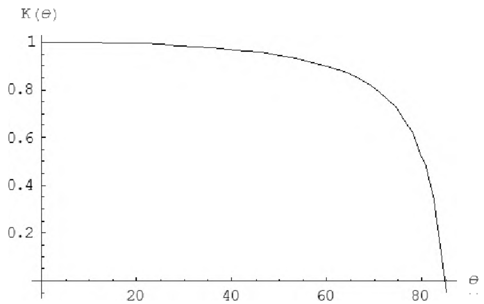
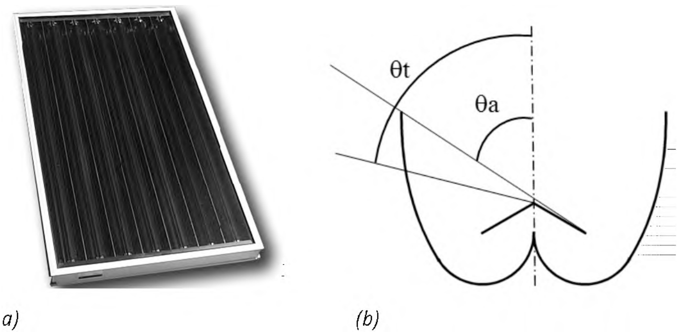


Fig. 2: flat plate incidence angle modifier

For CPC collectors the optical analysis is more complicated.

Fig. 3 shows a CPC collector (a) considered in this paper and its cross-section (b).



a) *(b)*

Fig. 3: (a) 1.15X CPC, (b) cross–section (acceptance angle θ_a *= 56.8° and truncation angle* θ_t*=76°)*

F'η_0 is measured at the same normal incidence (θ = 0) angle but the collector exhibits a bi-directional behavior, i.e., different in the transversal and in the longitudinal direction (see Fig. 1).

In this case F'η_0 is given by equation (4).

$$F'\eta_0 = F'\,\tau\,\alpha\,(\theta)\,\rho^{\langle n(\theta)\rangle} \qquad (4)$$

Where ρ is mirror reflectivity and <n> is the average number of reflections.

Fig. 4 shows the variation <n> with angle as a result of a detailed ray tracing analysis.

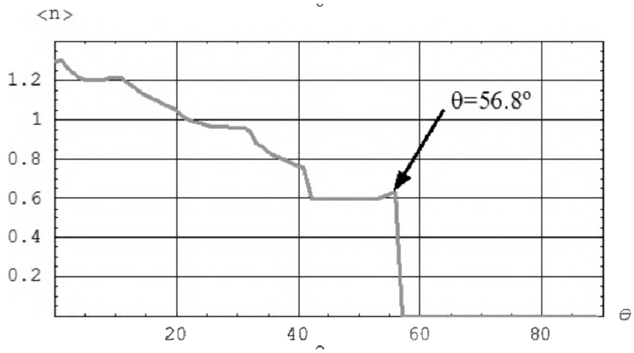


Fig. 4: average number of reflections as a function of incidence angle for the 1.15X CPC collector analyzed in this paper

In view of this it is easy to understand that, when CPCs are represented by their normal incidence test efficiency curve, they are being represented by a curve that is not at all close to the maximum possible, unlike flat plate collectors which are represented by their (maximal) efficiency curve, the one at normal incidence. In this sense, CPCs and other bi-directional collectors (like-evacuated tubular ones) should be more fairly represented by an efficiency band, as in Fig. 5, resulting from the application of eq.(4) and the variation of <n> with θ shown if Fig. 4 and ρ = 0.87.

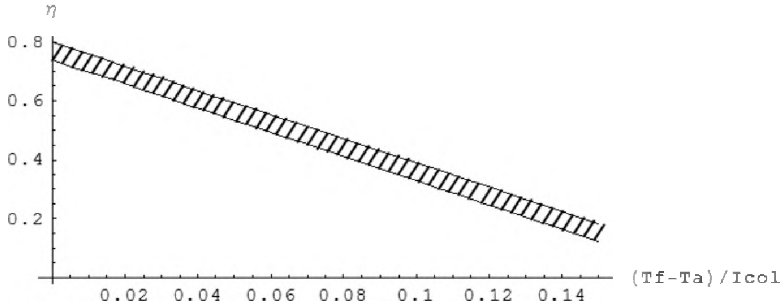


Fig. 5: efficiency band, 1.15X CPC collector (measured value at θ =0 is 0.74)

However in view of long term performance calculations, full optical behavior can be incorporated by considering incidence angle modifiers, both in the transversal and in the longitudinal directions (McIntire, 1982 [1]; Carvalho, 1987 [4]), and substituting $K(\theta)$ by the product $K(\theta_l, 0) \times K(0, \theta_t)$.

In the longitudinal direction the behavior of CPC collectors follows pretty much the behavior of flat plate collectors, since, in that direction, the optics is essentially determined by the existence of a glass cover, similar in the two collector types. Thus the appropriate incidence angle modifier will be just like the one in eq. 3.

$$K(\theta_l,0)= \tau\alpha\ (\theta_l)\,/\,\tau\alpha\ (0) \qquad (5)$$

But in the transversal direction the optical behavior is determined not only by eq. (4) but also by the fact that the CPC has an angular response (Rabl, 1985 [2]) as the one indicated in Fig. 6, for the 1.15X case analyzed in this paper, described by the acceptance angle function, the fraction of total incident radiation that is absorbed, for any given angle: all incident radiation is collected up to the acceptance angle θ_a and a small part is still collected up to the truncation angle θ_t.

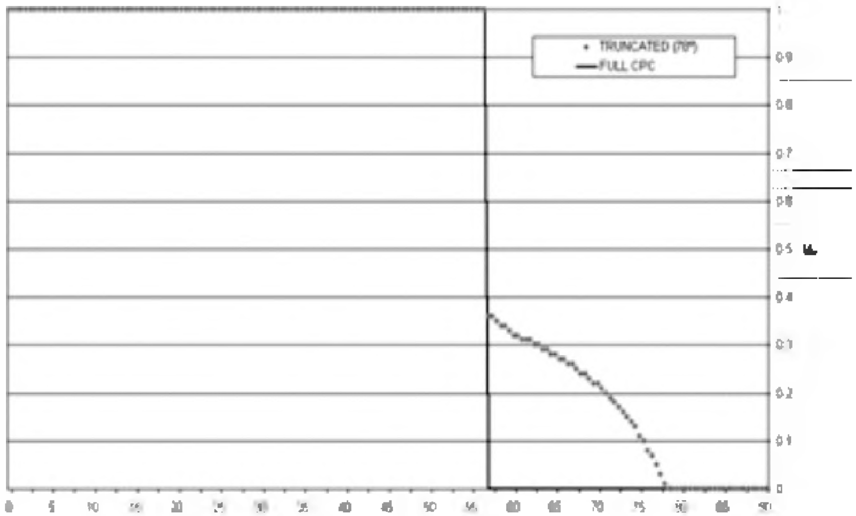


Fig. 6: angular response F(θ) of the 1.15X CPC (the curve is symmetric with respect to zero)
(Note: for flat plate collectors, F(θ) = 1 for all angles)

Folding the variation of optical efficiency with incidence angle with the angular response of Fig. 6, a transverse incidence angle modifier like the one in Fig. 7 is obtained.

Efficiency standards recognize the need to characterize the collectors by requiring that both incidence angle modifiers be measured. The longitudinal one as explained above and the transversal one by specifying measurements at 0°, 20°, 40° and 60°. To exemplify a possible outcome of such measurement, a broken line connecting those points is signaled in Fig. 7.

In (Carvalho, 1987 [8]) it is shown that assuming the solid line of Fig. 7 or the broken line coming from the measurements, when compared with a full ray tracing analysis, results in a small error (<2%) in the calculation of energy delivery.

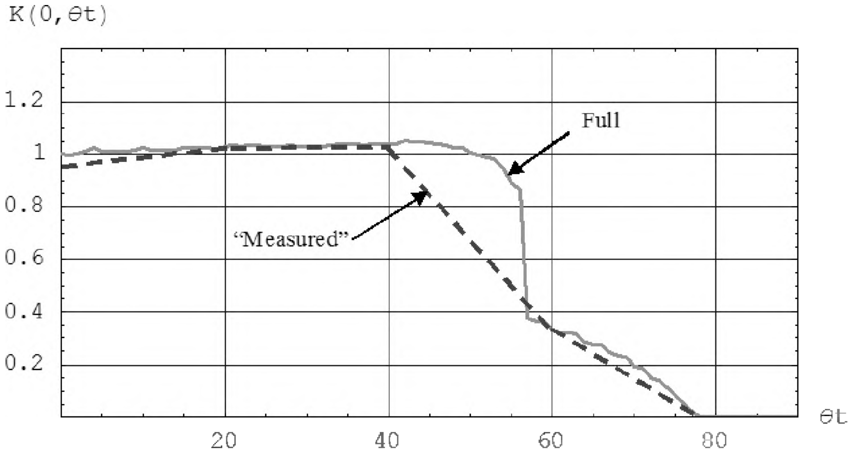


Fig.7: solid line: full transverse incidence angle modifier K(0, θ_t); broken line: "measured" incidence angle modifier

III – Suggesting a correction to the standard use of parameters obtained in efficiency measurements, in view of more accurate long term performance calculation

Long term performance calculations are usually based on the integration of the instantaneous energy delivered between sunrise and sunset, whenever the integrand is positive (equation 6), i.e. whenever gains are larger than losses.

$$Q = \int_0^t \dot{Q} dt = A_{col} \int_0^t \dot{q} dt \tag{6}$$

where $Q^{\cdot}$ is given by:

$$Q^{\cdot} = F'\eta_0 K(\theta) Icol Acol - a_1 (Tf - Ta) Acol \tag{7}$$

However a more correct equation would be to consider in eq.7, instead of $I_{col,}$ the quantity of radiation that is really absorbed by the collector $I_{abs.}$

$$I_{abs} = I_{b,n} \cos(\theta) K(\theta) F(\theta) + K_{dif,d} I_d F_d + K_{dif,r} I_r G_r \tag{8}$$

where I_{abs} incorporates all the information concerning the incidence angle modifiers referred above, through the separate handling of beam radiation, diffuse radiation and ground reflected radiation.

The coefficients K_{difd} and K_{difr} can be previously calculated for each collector type and global radiation broken in its beam and diffuse components.

(Carvalho, 1987 [8]) shows that for flat plate collectors, in a sunny place like Lisbon, calculating energy delivery with eq. 6 and 7 for flat plate collectors, or substituting Icol for Iabs (defined by eq.8), results in a small underestimation less than 1% (1.5% for Freiburg). However the difference can be much larger for concentrators (3–7%, for concentration values up to 1.5X).

This difference is very well calculated by simply considering a new efficiency definition η^* as defined by eq. (9) (Carvalho, 1987 [8]):

$$\eta^* = \frac{\dot{q}}{I_{abs}} = \eta \frac{I_{col}}{I_{abs}} \tag{9}$$

IV – Application considerations will be used in the performance comparison

Both aspects discussed in II and III are applied following (Carvalho, 1987 [8]) in the comparisons below, therefore treating both flat plate and CPCs in a consistent and complete way.

Table 1 summarizes the efficiency curve parameters of the collectors considered: a normal non-selective flat plate collector, a selective flat plate collector of high quality (single glazed) and the 1.15X CPC (standard product of AO SOL Energias Renováveis S.A. [9]).

Collector	$F'\eta_0$	$F'U_L$
Flat plate n/selective	0.76	7.6
Flat plate selective	0.80	4.7
1.15X CPC NS	0.74	4.11
1.15X CPC EW	0.74	4.05

Table 1: efficiency curve parameters of the collectors considered

The CPC collector can be used in NS or EW orientation mode, the first typically for thermosyphon systems and the second in forced circulation ones.

The computer program used (SolPro, developed at AO SOL [9]) is very similar to standard computer programs like the official SOLTERM [10] program used for certification purposes in Portugal, but is already corrected to include the different aspects referred above.

Results of energy delivered on average per year, in Lisbon (Portugal), and Freiburg (Germany) are shown in Table 2.

	ENERGY DELIVERED FOR LISBON KWh/(m2*year)				ENERGY DELIVERED FOR FREIBURG KWh/(m2*year)			
Tin (ºC)	Flat plate n/selective	Flat plate selective	1.15X CPC NS	1.15X CPC EW	Flat plate n/selective	Flat plate selective	1.15X CPC NS	1.15X CPC EW
30	908.2	1112.6	1021.8	1080.9	437.2	621.3	590.1	625.8
40	699.3	957.9	884.7	944.0	310.8	507.8	487.4	522.0
50	530.6	821.8	763.6	822.1	220.3	415.4	402.9	435.8
60	393.7	702.0	656.4	713.6	154.5	339.8	333.2	364.0
70	282.1	596.3	561.4	616.8	105.5	277.8	275.4	303.9
80	190.7	502.9	477.1	530.3	67.8	226.6	227.2	253.5
90	115.6	420.3	402.2	452.9	36.9	184.2	187.0	210.9

Table 2: results of energy delivered on average per year, for Lisbon (Portugal) and Freiburg (Germany). For collector tilt β *=latitude.*

They show that the CPC collector and the very good flat plate are very similar in performance at lower temperatures but once the temperature exceeds 60 °C the 1.15X CPC has already a little higher performance.

V – Conclusions

Solar Collectors are usually described by their efficiency curves, measured by standard procedures by accredited institutions.

These curves can not be directly compared, when corresponding to different collector types. They must be completed with the respective incidence angle modifiers. For bi-directional collectors (like the CPCs) these are quite different in the longitudinal and in the transversal directions.

When calculating collector performance these bi-directional behavior must be properly taken into account as well as the fact that the instantaneous solar radiation value that should figure in the heat balance equation used, is not the one used to obtain the standard efficiency curve and measured by the pyranometer on the collector plane, but the one really being absorbed by the collector, already taking into account the whole of collector optics. Not doing so has larger consequences for the concentrators than it does for flat plate collectors, and that influences collector comparisons.

It is shown that a single glazed CPC collector of very low concentration (C = 1.15X) delivers much more energy than a regular flat plate collector and as much energy as very good single glazed flat plate collectors, being at an advantage when the operating temperature is higher. In fact this is to be expected since they were designed for the DHW market, thus not taking full advantage of the fact that they can deliver more energy at higher temperatures, if a higher concentration value was used. In fact higher temperature applications, like cooling or desalination will require energy delivery at higher temperatures (above 80 °C), and new non-evacuated CPC collectors, with smaller heat loss coefficients, will be able to deliver even more energy, giving them a chance of becoming a technology of choice for those applications, since they can be built with similar costs as those of very good flat plates and posses an identical durability/reliability.

Nomenclature

$F'\eta_0$, optical efficiency
η, instantaneous collector efficiency; ρ, reflectivity
τ, transmissivity; α, absorptivity
$\langle n \rangle$, average number of reflections for a given incidence angle; θ, incidence angle [º]
K, incidence angle modifier; $F(\theta)$, acceptance angle function
θ_t, incidence angle projected in the collector transversal plane [º]
θ_l, incidence angle projected in the collector longitudinal plane [º]
I, efficiency curve base radiation [W/m^2]
I_b, beam radiation [W/m^2] ; I_d, diffuse radiation [W/m^2]
I_r, reflected radiation [W/m^2]
I_{col}, global hemispherical radiation incident on the collector aperture plane [W/m^2]
K_{dif}, average hemispherical incidence angle modifier
C, concentration factor; β, tilt angle [º]
T_f, mean collector fluid temperature [ºC]
T_a, ambient air temperature [ºC]
F', collector heat transfer factor
$F'U_L$, global heat loss coefficient, [W/(m2.ºC)]
$Q^{\cdot}$, collector instantaneous power, [W]
$q^{\cdot}$, collector specific instantaneous power, [W/m2]
A_{col}, collector aperture area [m2]
a_1, global heat loss coefficient, corrected with the heat transfer factor, [W/(m2*ºC)]
Tin, fluid temperature at inlet of collector, [ºC]

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[10] SOLTERM computer program sold by INETI, certified for the calculations of solar collectors performance in buildings.

Evolution of the Solar Water Heating Labeling Program

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Introduction

In 1997, through a joint action it enters National Institute of Metrology, Standardization and Industrial Quality (INMETRO), the Association of Refrigeration, Air-Conditioning, Ventilation and Heating (ABRAVA) and the Group of Studies in Energy (GREEN), located in the – Pontifical Catholic University of Minas Gerais, was created the Center of Reference in Thermal Solar Energy, hosted in GREEN, and implemented the Labeling Program (PBE), which represented a landmark of evolution and quality in the industrial sector of national solar water heating.

In the first stage, the labeling program of solar collectors, thermal boilers and connected systems is voluntary in Brazil, investing in the improvement of the laboratorial capacity of the country and in the adequacy of the companies to the considered tests. The cast of tests have been continued adjusted to reaches the totality of the procedures and tests established for International Standard ISO 9806-1, 2 and 3, as soon as possible.

So far, 423 products of 60 companies had been tested, searching to improve the quality of the available solar collectors in the market, exempt mechanisms for industrial and marketing competitiveness, beyond facilitating the implementation of incentive programs to the exportation of these products.

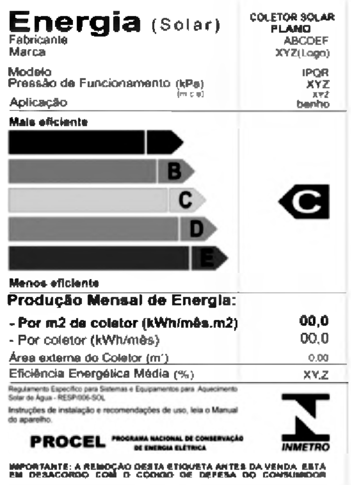
To guarantee that such improvement equally reflects in the quality of the installations of solar water heating for domestic and swimming pool applications, many initiatives with financial supported by the Science and Technology Ministry had been taken, through the Studies and Projects Financier (FINEP) and /PROCEL.

The creation of a work group with the participation of specialists in solar heating is distinguished with the Association of Technical Standards (ABNT), for the standards elaboration of products, projects and solar water heating systems installation. Simultaneously, programs of qualification of teachers had been implemented, which were applied by presence classes and distance learning courses, for them to act as multiplying agents in the formation of designers and installers to supply the market demand, amongst the activities, the evaluation of finished installations.

SOLAR COLLECTORS LABELING PROGRAM

This program is directed in Brazil for the lay consumer, creating an easily understood comparison criteria relating the different products. The results of the tests are presented in the INMETRO Label, similar to the household-electric label already used. Fig. 1(a) shows the solar collector label version that has been in use since 2005. At the top, the label presents basic information including manufacturer, brand, model, maximum working pressure and application (domestic or swimming pool). Below the graphic classification, the label presents the average monthly energy production (kWh/month), the average specific monthly energy production (kWh/month.m^2), the label sets out the gross collector area (m^2) and the average collector's thermal efficiency (%).

Currently, the labeling program adopts a classification with 5 different categories, from A to E, according the average specific monthly energy production in kWh/month.m^2, showed at Fig. 1(b). This information is generated experimentally from the resultant parameters of the instantaneous thermal efficiency and incidence angle modifier data linear adjustment, applied to one day standard, decided for the typical climatic conditions.



(1a): INMETRO label

Aplication: **DOMESTIC**

A > 77 kWh/month.m^2
77 ≥ **B** > 71
71 ≥ **C** > 61
61 ≥ **D** > 51
51 ≥ **E** > 41

Aplication: **SWIMMING POOL**

A > 95 kWh/month.m^2
95 ≥ **B** > 87
87 ≥ **C** > 79
79 ≥ **D** > 71
71 ≥ **E** > 63

(1b): Classification Score

Fig. 1: INMETRO label and classification score

PROCEL Stamp of Energetic Efficiency

PROCEL stamp has the purpose to stimulate the manufacture to produce more efficient products by means of energy economy, guiding the consumer in the act of acquiring these equipments, in order to contribute for the technological development and the reduction of ambient impacts.

PROCEL stamp, shown in Fig. 2, is annually granted to the equipments that present the best level of energy efficiency, i.e., characterized for the classification "A" obtained at the INMETRO label. PROCEL stamp have been granted for solar collectors since 2000, being possible to identify an expressive improvement in the thermal performance of these products commercialized in Brazil.

Fig. 2: PROCEL Award

Indoor and Outdoor Tests Facilities

With the evolution of the market, through an action of the government in a partnership with /PROCEL, supported by the United Nations Development Programee (PNUD), financial support of World Bank (BIRD), by means of the Global Environment Facility (GEF), in December of 2004 was inaugurated the Laboratory of Indoor Tests in GREEN equipped with the first Solar Simulator in Latin America.

The Solar Simulator is consisted of 8 metal halide lamps with individual power of 5 kW each and the second with artificial sky in the world. This Solar Simulator is considered the highest level, class 1, on the basis of the requirements of specter, uniformity and timing variability of the incident radiation in the test area.

The GREEN operates with external and internal benches, which allow the validation of the outdoor and indoor solar simulator results generated by tests between the benches. The graph of Fig. 3 evidences great matches between the results, attributed to the quality of the instrumentation used in attendance to the requirements of precision and accuracy of the international standards and to the presence of the artificial sky that guarantees comparable radiating losses to the energy exchanges with the celestial vault in the external ambient tests.

The graph of Fig. 4 shows the experimental uncertainty and the relative error in the indoor test for a typical solar collector. The results demonstrate respectively that the uncertainty varies slightly between 2,1% and 2,2% for the band of thermal efficiency evaluated between 48% and 72%. As expected, the relative errors decrease with the increase of the thermal efficiency.

In result of the reduction of the time for accomplishment of the tests, since September 2005 the tests of accompaniment of the production have been implemented in the labeling program. With support of GREEN, annually the INMETRO convokes for new tests 1 of each 5 model solar collectors commercialized for company, obeyed to the two applications bath and swimming pool.

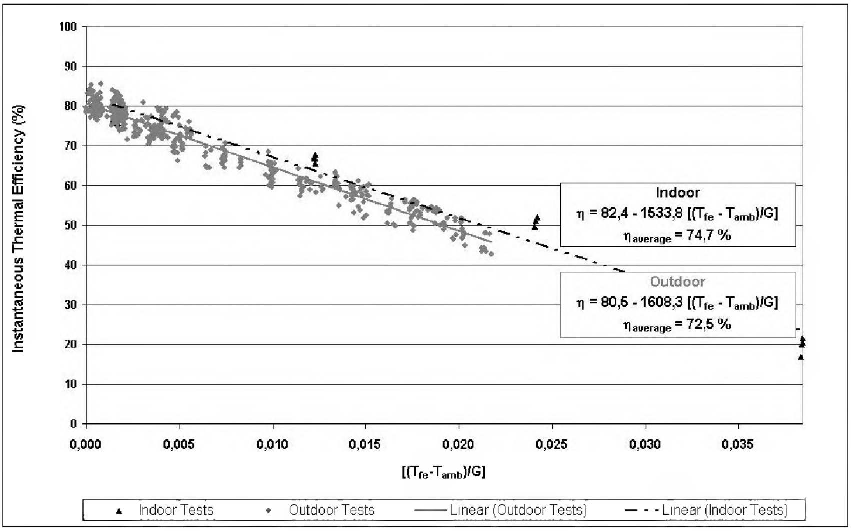


Fig. 3- Comparative curve of outdoor and indoor solar simulator thermal efficiency tests for a typical solar collectors

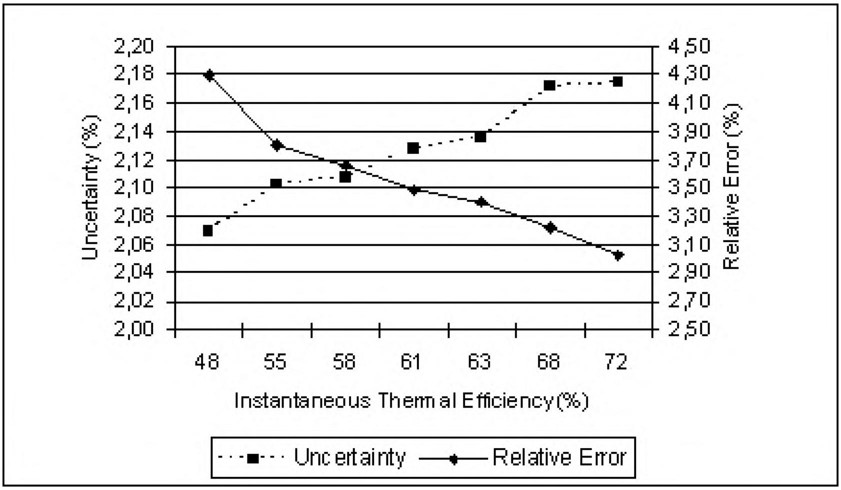


Fig. 4- Behavior of the expanded uncertainty and the relative error in function of the thermal efficiency for a Brazilian typical solar collector

Conclusions

The Brazilian Labeling Program of Solar Collectors has been as a vector of quality and training continued for the laboratory GREEN and its team of technician.

The manufactures has improving their products using the facilities of the laboratory GREEN, which outdoor and indoor solar simulator tests. Its functioning allows the greater agility in the tests of thermal efficiency, stimulating them to develop the products and invest in new technologies.

In 2007, studies have been made to become the program obligatory, in order to evaluate the totality of solar collectors commercialized in Brazil, which would guarantee products of good quality, thermal performance and trustworthiness to the final consumer.

SolarKeymark – experiences with the European solar thermal quality label

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Many aspects come to mind when thinking and talking about technically reliable and long-time durable solar thermal products. The following paper tries to answer some of the frequently asked questions concerning the SolarKeymark. These ideas and information can be used as a guideline by all who are interested in the SolarKeymark label.

How can a high quality standard of products be ensured in the market?

This question concerns products in general and not specifically solar collectors and solar thermal systems. First – what seems to be obvious but is not trivial – one has to be aware of possible deficiencies of the product. These have to be analyzed so one really knows the reasons for failings and malfunctions.

The next necessary step is, of course, to solve these problems and search for an adequate solution. The new solutions have to be brought into production and have to be implemented in the standard production procedure. At the end of this development process of continuing improvements there is the target product.

Then a testing of the final product can be carried out by an external and independent laboratory to show the quality reached and to describe the product in an objective and comparable way. The result of the test can be used to apply for a quality certification. Routine quality supervision can be used in order to ensure the constant level of quality during all the time the product is sold.

How can such a process be implemented? How can this process be standardized, so that it is done in the same manner from different actors?

There is already a label for quality supervision installed in the European Union by CEN (Comité Européen de Normalisation): this label is called Keymark.

There are rules and procedures defined how to install a quality supervision system for products traded in the EU in general. Within the Keymark rules it is necessary to define and adopt individualized rules which concern the needs and difficulties of the products concerned. These definitions are called "Scheme Rules".

This Keymark system can be used to install quality supervision in the field of solar thermal products. The Keymark adopted for solar thermal products is called “SolarKeymark”.

How to have an eye on the technical reliability?

The solution to this question within the Keymark framework is that the Scheme Rules include the requirements of the recent, valid standards concerning the particular product. This is also the case for the SolarKeymark Scheme Rules. They refer to the standards EN 12975-1,2:2006 for solar thermal collectors and EN 12976-1,2:2006 for factory made solar thermal systems.

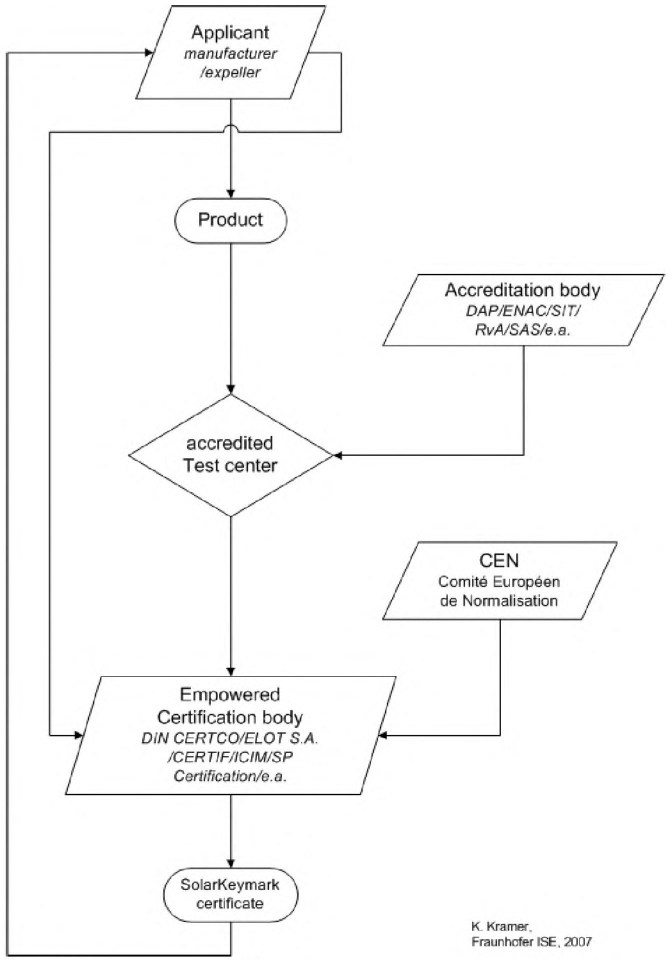

Fig. 1: Structure of SolarKeymark procedure

Who is involved in the SolarKeymark-procedure?
What are the steps to get a SolarKeymark on a product?

Please see Fig. 1 to get an overview for the answer to this question:
The process starts with a manufacturer willing to certify his product. First he will contact the accredited test laboratory he wants to work with. The laboratory will inform him about the different possibilities and details concerning his individual case. The discussion will end in an order for testing the product according to the Scheme Rules.

The test laboratory will start the procedure of testing, production inspection and SolarKeymark process.

The test laboratory has to be accredited by an accreditation body. These are national bodies supervising laboratories and accrediting them for tests according to defined standards. These bodies have an alliance called ILAC. Bodies which are members of this ILAC stated with their signature in the so-called Mutual Recognition Arrangement that accreditation given to a testing laboratory by any of the ILAC members is accepted by any other member.

After finishing the testing and having done the production inspection the test center will hand the test report to the manufacturer.

The manufacturer now has testing results and can apply for the SolarKeymark at the empowered Certification Body. These Certification bodies have to be empowered by the owner of the Keymark label (CEN) to be allowed to issue the label to applicants. After receiving the application and test report the empowered Certifier will contact the test laboratory and ask for documentation of testing and inspection. Everything will be prepared by the laboratory and send to the certifier. This body then checks the documentation and hands out the certificatein the case that all requirements are fulfilled.

The certificate is valid for the product, which is in detail defined within the testing report. Of course, if the product is just sold with the same name by an OEM costumer of the manufacturer the label stays valid. If the OEM costumer changes the products name the manufacturer contacts the test laboratory again. There will be made a version of the original test report to validate the new product name. Using this version of the report the OEM costumer can contact the empowered Certification body for getting his own certificate.

What is the use of getting a SolarKeymark certificate?

Many European countries accept the SolarKeymark label as the quality label, on which covers national requirements for subsidy programs. The number of countries is still growing. Manufacturers holding a SolarKeymark on their product can ensure in these countries to their end costumers that the product fulfills requirements for applying for subsidies.

In consequence, another great advantage of the SolarKeymark is the cost reduction for testing. With SolarKeymark implemented now, only one test on the collector is necessary to penetrate the markets of all countries accepting the SolarKeymark.

Of course, there is another obvious advantage. End costumers have and will have growing trust in the quality label. The label gives them a helpful orientation within the growing market.

Another advantage is that the products are tested thoroughly and possible deficiencies would be detected. Manufacturers therefore have the possibility to react on this before spreading the product widely on the market.

An integrated part of the SolarKeymark procedure is a visit of the production factory and an inspection of the quality management of the production. It is regarded as an additional advantage of the SolarKeymark procedure that manufacturers become more aware of their responsibility for their product and the way it is produced.

Last but not least, the combination of technical quality tests, quality management inspection and checking on service items like manuals is a powerful tool to increase the minimum quality standard of products sold in the market. The aim is to protect the branch of low quality products where costumers could make bad experience on, what would harm the reputation of this technology.

What is situation now and what will go on?

The SolarKeymark is widely accepted all over Europe and the number of countries accepting is growing and it will grow further. It is a successful system in many countries right now already.

Also the acceptance at manufacturers is already high and it is growing as it protects their quality and proved to be a good argument for sale.

It is very important that the standards, which the Scheme Rules refer to, are developed in such a way that in consequence of the interdigitating processes of subsidy, quality label and standards, new and innovative technologies are not blocked from market. This point also has to be kept in mind when thinking about the specific Scheme Rules.

It seems that the ongoing harmonization of the European market and increasing participation of manufacturers world-wide will confirm the success of the SolarKeymark also in the future.

References

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Developments in the field of coloured solar collectors

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INTRODUCTION

There are many influencing factors how the use of solar thermal systems could be enlarged. Besides the subsidies support and regulated energy prices, the technical issues can play important role. Many of the studies (1–3) conclude that coloured solar absorbers (collectors) could be much more acceptable for building planners and architects and also for building owners and potential users than the ordinary black one. Paper presents two new technologies of coloured solar collectors – solar tiles and glazed coloured flat-plate solar collectors – together with their thermal characteristics determined by series of experimental and numerical analyses.

SOLAR TILES

Solar tiles are unglazed large area solar collectors compounded of hollow transparent tiles made from thermally and UV resistant polycarbonate, developed by Slovenian company GeaSol International (4). Tiles can be produced in different forms that suit the basic form of building roof tiles. This enables integration of solar collector into the roof without any visible joining elements. The absorption of the solar radiation is provided by coloured heat transfer fluid (HTF) circulating in solar tiles. Heat transfer fluid is a mixture of water, freezing protection fluid and liquid or powder colour, which can be selected in such a way to enable complete integration with the building roof tiles. For research purposes black, reed, green and blue colour were used. Fig. 1 shows solar tiles used in experiments.

First solar tiles with the black HTF were tested. Fig. 2 shows measurement results for solar tiles with black and red coloured heat transfer fluid. Efficiency determined by experiments according to the EN 12975-2 is:

$$\eta = \eta_0 - (11.23 + 3.9u)\frac{T_m - T_a}{G''}$$

where η_0 is equal to 0.745 for black coloured HTF and 0.553 for red coloured HTF. In the equation G'' represents net solar irradiance on the collector plane, u is a wind speed, T_m is mean HTF temperature and T_a is ambient air temperature. Lower η_0 as expected is a consequence of over-covering of solar tiles, strengthening ribs in tiles and tile edges which all reduce the actual solar collector aperture area. Lighter colours and thus lower solar absorptance additionally reduces η_0. The later can be compensated with corresponding enlargement of overall solar tiles area.

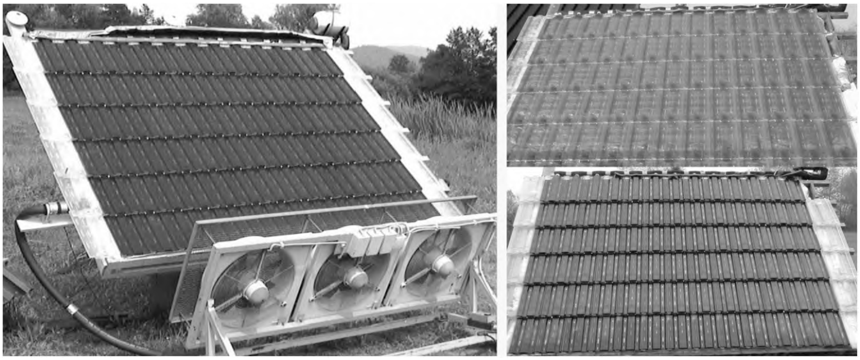

Fig. 1: Solar tiles; (left) solar tiles with black HTF under test, (right) appearance of light red and dark green solar tiles

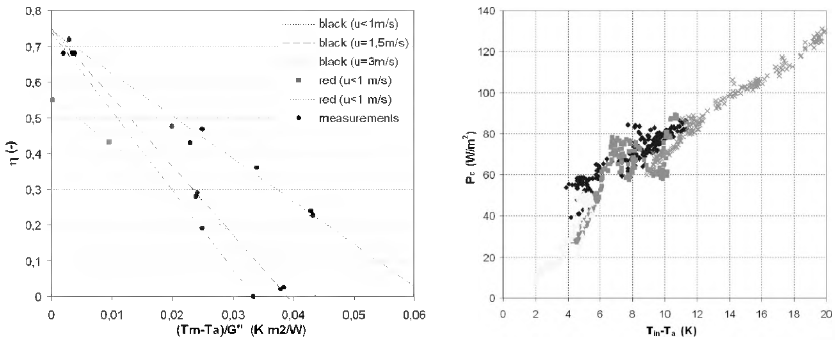

Fig. 2: Experimentally determined efficiency of solar tiles with black and red coloured HTF (left) and night time cooling power (right): clear sky (◆, ✖) overcast sky (■), cloudy sky (▲)

Solar tiles are in development stage and will be available also as a factory made system with 5.2 m² of solar tiles and 300 l heat storage. Such system was tested according to ISO 9459-2 and the following characteristic was obtained for the daily energy output of the solar system (Q [MJ/day]):

$$Q = 1.382 \ \ H + 0.406(T_a - T_{main}) + 0.902$$

This equation is valid in case of black coloured HTF. In equation H epresents daily solar irradiation on a collector plane (MJ/m^2), T_a daytime ambient temperature and T_{main} cold water supply temperature.

Because the solar tiles are unglazed solar collectors made from polycarbonate they can be used for radiant cooling in the night time. In connection with floor or wall heating system it can provide cooling for the building. Fig. 2 shows experimentally determined solar tiles cooling power at different sky conditions (clear, cloudy).

Applicability of unglazed solar collectors is mostly limited to low temperature applications or warmer climatic conditions (Mediterranean). Otherwise solar collectors should be glazed. Such technology of coloured solar collectors is introduced next.

Coloured glazed flat-plate solar collectors

The absorbers of solar collectors are made from Al sheet in roll-bond technology. They were developed in collaboration by University of Ljubljana and company Gorenje Tiki (5). Arrangement and number of absorber tubes is optimized in order to achieve uniform flow and high collector efficiency factor F'. This is important for achieving high η_0 especially because the absorptance of colours is lower than at black one. Due to the roll-bond technology used for the absorber production only paints can be used as a cost effective coating. Absorbers are painted with coloured semi-selective paintings developed by the National Institute of Chemistry in Slovenia (6). Fig. 3 shows prototype glazed coloured flat-plate solar collectors in brown, blue and green colour.

Fig. 3: Coloured glazed flat-plate collectors painted with brown, blue and green semi-selective paints

Three solar collectors with different absorber colours were tested. Used semi-selective paints have the solar absorptance α_s between 0.63 and 0.88 and the thermal emittance ε_T between 0.32 and 0.4. Fig. 4 shows the efficiency of solar collectors determined with experiments according to the EN 12975-2.

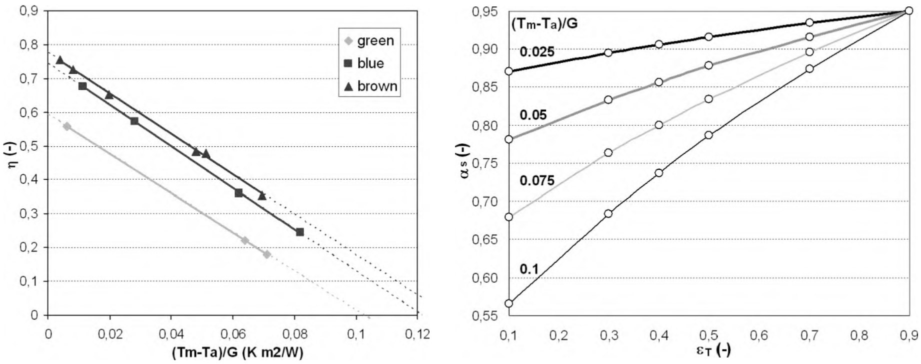

Fig. 4: Efficiency of prototype coloured solar collectors (left) and chart of equal efficiencies of coloured collectors (different combinations of $\alpha_s : \varepsilon_T$) compared to the black painted collector ($\alpha_s = 0.95$, $\varepsilon_T = 0.9$).

Thermal efficiency of coloured solar collectors can't compete with selective one, but it can have advantage compared to black painted solar collectors due to lower thermal emittance of semi-selective colours. The verified numerical model of the heat transfer in the solar collector (7) was used for developing the chart of equal efficiencies. The chart enables determination of arbitrary combination of $\alpha_s : \varepsilon_T$, which assures equal efficiency of the coloured solar collector as the solar collector painted with the black colour ($\alpha_s = 0.95$, $\varepsilon_T = 0.9$). This chart is presented in Fig. 4 for four different values of $(T_m - T_a)/G$.

Conclusion

Article presents two new technologies of coloured solar collectors – unglazed transparent solar tiles with coloured heat transfer fluid and glazed coloured flat-plate solar collectors painted with semi-selective paints. If high thermal efficiency is not a limiting criteria both of presented technologies can contribute to the EU targets for solar thermal systems.

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Development of the Solior FL150 solar water heater

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Introduction

The Solior FL150 is a new type of compact solar water heater for single family houses and apartments. It is a so called Integrated Collector Storage (ICS) solar water heater, in which the tank is also the collector. The cylindrical pressure tank is backed by two involute mirrors to boost the yield (see Fig. 1). The FL version is for flat roofs. A version for sloped roofs (SL) will be available in autumn 2007.

Fig. 1: The Solior FL 150 solar water heater

Innovation

Although the basic principle of this type of system is well known [ref.1], there are a number of new (patented) developments in this system, such as the optimisation of the optical efficiency and heat loss over the height of the tank. There is for example no traditional insulation material in this system and no transparant insulation material (TIM). A low heat loss ($U = 2\ W/m^2/K$) is achieved by the application of a very good spectral selective layer ($\varepsilon = 0.05$). Moreover the hottest part of the tank (the top part) is insulated by a PC transparant convective barrier and by an extra aluminium radiation mirror at the top of the tank.

DST TEST AND F-CHART METHOD

An official DST test of a prototype according to EN12976.2 was performed by INETI in Portugal. Table 1 gives some results of the test.

Location	Yield: Q_l (GJ/year)	Yield: Q_l (kWh/year)
Stockholm (Irradiation H_{inc}: 3.9 GJ/year)	3.081	866
Wuerzburg (Irradiation H_{inc}: 3.3 GJ/year	2.640	733
Davos (Irradiation H_{inc}: 6.0 GJ/year)	4.762	1322

Table 1: Results of the DST test at INETI at 140 litre/day hot water demand

With the improvements made for the production model, we expect a 10% higher yield from a new DST test (summer 2007). Other tests according to EN12976/75 are running.

In Spain the f-Chart method is used to calculate the yield of solar systems. In general this method is accepted by the authorities. Since the Solior system has a curved aperture, the effective aperture is bigger than the aperture projected on a flat plate (1.85 m²). This difference can be expressed with the average incidence angle modifier (IAM). This value is around 1.08 (so higher than 1) over the day. This gives an effective aperture of 2.0 m². Because of the mirror behind the top part of the tank, the effective angle of incidence is also somewhat bigger than the angle of the frame of the system (from 20 degrees to an effective 25 degrees). The f-Chart can be filled in according to Table 2.

Collector area	2	m^2
Collector inclination	25	degrees
Storage	150	l
Collector optical efficiency (η_0)	0.72	%
Average heat loss coefficient collector	2.0	$W/m^2/K$

Table 2: Parameters for f-Chart calculation

With the parameters thus adjusted the results are in agreement with the results of the DST test. We can now use the f-Chart to calculate the yield for different locations. This gives for Barcelona a yield of 5.4 GJ/year (1500 kWh/year), for Madrid a yield of 6.1 GJ/year (1700 kWh/year) and for Sevilla 6.2 GJ/year (1720 kWh/year) at a hot water demand of 140 litre/day. In Spain and some other countries it will be sold by Ecostream under the name Sunstock.

Demonstration project

A demonstration project was performed with ten prototype systems. Eight systems were installed in the Netherlands and two in Spain. The project was supported by the EOS-DEMO programme of SenterNovem in the Netherlands. From the eight systems in the Netherlands, seven were placed at individual households and one was placed on top of the Econcern main office building. This system was monitored more extensively in order to validate the simulation program. All house systems performed well and no repairs were necessary, only the inner ventilation of the system was improved during the monitoring year. We measured the hot water demand and the yield of the systems. Fig. 2 gives the yield from the monitoring as well as the simulated yield for the systems in The Netherlands (monitoring from 1 Jan. 2006 to 1 Jan. 2007). Three of the seven systems had some shadowing over part of the day and we corrected for that (system B (−24%), C (−17%) and E (−13%) of irradiation). For the simulation we used irradiation data and ambient temperature data from the central Dutch meteo station in the Bilt. The yield is somewhat reduced by the August holidays (around three weeks away from home) and the fact that 2006 had an irradiation (3.6 GJ/year) around 10% lower than average. Moreover there was a general tendency to use more hot water in winter than in summer.

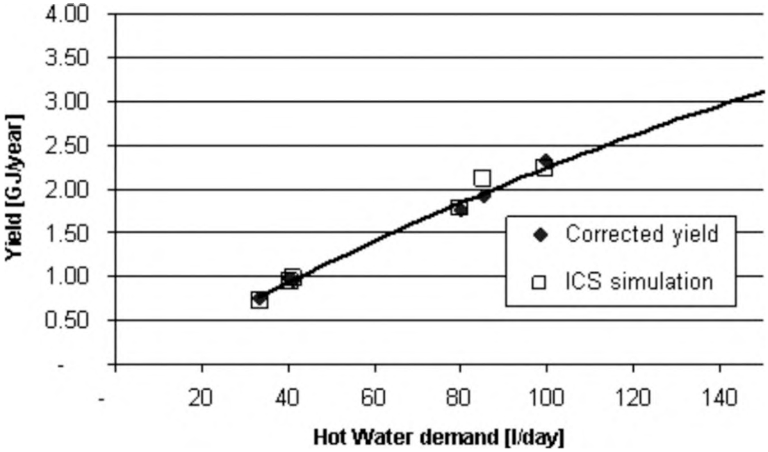

Fig. 2: Yield over the monitoring year as a function of the hot water demand as well as the simulated results (demonstration project in The Netherlands).

The two systems in Spain were also placed at individual households. These systems functioned well too. At one of the two systems the occupant even decided to shut off the (natural gas) auxiliary heater from April to October. The heater was switched on again in October because there was a demand for space heating. Apart from this demonstration project there is also a field test running in the Netherlands with a previous prototype. The one Ecofys monitored is working properly for ten years now.

Freeze protection

The ICS solar water heater is protected against freezing by a thermostatically controlled drain valve which opens when the temperature at the bottom of the tank is below 3 °C. Fresh water from the water mains flows into the tank and this will raise the temperature of the tank. Since the thermostatic control is mounted at the outlet pipe of the tank, this system protects both the inlet and outlet connections. In the rare occasion that the drain system fails, the chances of damage by freezing are still extremely low. According to a simulation of an extreme low temperature test for The Netherlands (according to EN12976-2 Annex C; 14 days of a constant −9 °C, only 0.3 MJ/m^2/day irradiation and no water use) the tank will never completely freeze. As long as the connection pipes are open by heat conduction from the house (for which the roof penetration set is specially designed), the tank will not be damaged, because the expansion of the freezing water can be relieved over the pressure relief valve. With pipes outside the house (common in Spain), the pipes should be protected with a thermostatic heating cable (only for locations with a risk of freezing).

Overheating protection

The ICS solar water heater is protected against overheating by a thermostatically controlled drain valve which opens when the temperature at the top of the tank is over 85 °C. Fresh water from the water mains flows into the tank and the hot water flows through the drain valve to the sewer. When the temperature at the top of the tank is reduced to about 75 °C the drain valve is shut again. The opening of the drain valve is a rare event, since it will only happen when there is no use of hot water over a number of days during which there is a high irradiation (clear sky). We expect on average a drain of less than 100 litre/year for freeze and overheating protection together.

The maximum temperature that the water in the tank can reach for three different locations (if the thermostatic drain system fails) was calculated. We used the warmest day from the test Reference Year of The Bilt for The Netherlands (and Meteonorm for Spain) and combined this with the day with the highest solar irradiation. This day-pattern was repeated for 14 days in a row. The thermostatic valve was switched off and there was no hot water use. The tank can reach a temperature between 110 and 120 °C at most. No steam is formed since the tank is pressurized. The mechanical mixing valve will reduce the temperatures of water withdrawl to a safe level (around 60 °C) by mixing hot water with cold mains water, even if the temperature is higher than 100 °C.

Design

The system was developed for easy handling and installation, very low maintenance, high durability, an attractive design and a competitive price. The system is relatively light weight (60 kg) and is easy to lift and to handle. The installation is simple, only the inlet and outlet pipe have to be connected as well as a 4-wire cable and the pre-assembled control unit. To conduct the pipes directly through the roof, we designed a special roof penetration set.

It has hardly any maintenance. It has no anti-freeze liquid which has to be replaced every five years and checked every year. It has a stainless steel tank which has no anode (replace every five years) as a glass lined tank has. Because it has no heat exchanger it also has no scaling problems (lime formation). It has no pump and no pump control. In very dusty countries it is advised to clean the transparent dome periodically.

For durability we have chosen materials that have been proven in building applications for more than 30 years now. The PMMA transparent dome is also common as a roof light and the black lower shell is made of HDPE regenerate, which is also a common material in roof constructions. Stainless steel as a hot water tank material has a good track record. An EPDM rubber gasket profile effectively closes the joint between the HDPE and PMMA housing shells; a moulded silicone gasket closes the piping connection. Production has started in May 2007.

At the end of its service life the system can easily be disassembled. There is no mixing of materials, so all the parts can be recycled. Most of the parts are already produced from materials with a high recycling percentage.

Conclusions

The Solior FL150 is an important new player in the market of solar water heaters.

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Dynamic Model of Solar Collector Based on Kalman Filter: Preliminary Reults

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Introduction

The necessity to introduce tests in transient conditions depends essentially on the facts that the collector testing under steady state requires stringent conditions (tests to be conducted under mid-day without sun following surface, clear sky and very low diffused radiation, fixed inlet flow rate and the temperature) and hence lengthy test period and high cost. Transient method enables testing to be extended over the entire day (with possible acquisition of much higher numbers of experimental data on the daily basis in comparison to the steady state method) without any strict condition of a clear sky. On the contrary, for an accurate and precise determination of different parameters it is necessary to test a collector under cloudy days, as well.

Testing under transient conditions takes into account the dynamic behaviour of collector through proper use of its thermal capacity or equivalent parameters thus making the model workable under real conditions. To avert problems and the limitations associated with the collector testing under steady state conditions, a test under transient conditions called QDT [1] has been introduced in the existing norms. A series of models and methodologies already proposed and, in most of the cases validated, as well, are reported in reference [2].

In this paper is implemented an innovative dynamic model for solar collector based on Kalman filter [4].

The starting point to develop the subject under investigation is to define a collector as a continuous linear system with a differential linear equation of the first order. The subsequent step is to obtain a time-discrete representation [3] of the type:

$$\overline{T_m}(k+1) = p_0\overline{T_m}(k) + p_1 G_{dir}(k) + p_2\overline{T_i}(k) + p_3\left(\frac{1}{\cos\theta(k)} - 1\right)G_{dir}(k) + p_4 G_{diff}(k) + p_5\frac{dT_a(k)}{dt} \quad k = 1,2,3,....$$

In the time-discrete equation, parameters p_i will be determined using the procedure known as "Kalman Filter".

The representation of the model with a discrete time equation and the identification of parameters by means of Kalman filter has the following advantages:

- Possibility of using large set of measurements in comparison to the limited parameters in a stationary test;
- Possibility of on-line identification in real time with possible use of advanced method with digital control for efficient and effective control of a solar system;
- Application of an identification methodology that take care of problems associated with measuring chain;
- Easy to use collector model in automatic calculation programmes;
- Test conditions that do not require fixed values for thermal fluid dynamic parameters;
- Significant reduction of time needed for identification.

Determination of discrete time system parameters by means of Kalman filter [4]

The collector model can be expressed in the form:

$$y(k) = p_0 y(k-1) + p_1 u_1(k-1) + \ldots\ldots + p_5 u_5(k-1) + v(k)$$

where u_k are the inputs and $y(k)$ is the output with the following expressions:

$$u_1(k-1) = \overline{T}_i(k-1)$$

$$u_2(k-1) = Gdir(k-1)$$

$$u_3(k-1) = \left(\frac{1}{\cos(\vartheta(k-1))} - 1\right) Gdir(k-1)$$

$$u_4(k-1) = Gdiff(k-1)$$

$$u_5(k-1) = \frac{d}{dt} T_a(k-1)$$

$$y(k) = \overline{T_m}(k)$$

In the model it has been assumed that the output is affected by errors represented by a Gaussian white noise $v(k)$.

Indicating with "p" the vector of parameters $p = (p_0 p_1 p_2 p_3 p_4 p_5)^T$, it is possible to write:

$$p_i(k+1) = p_i(k) + w_i(k)$$

where $w_i(k)$ and $w_j(k)$, with i≠j, are indipendent Gaussian white noises.

Knowing the values of $y(k)$ and $u(k)$, the system parameters p_i can be estimated using Kalman Filter. Considering the system whose state and output are p and $y(k)$ respectively:

$$p(k+1) = p(k) + w(k)$$
$$y(k) = C(k)p(k) + v(k)$$

where:

$$C(k) = [y(k-1).....u_1(k-1).....u_5(k-1)]$$

the Kalman filter provides the estimation $\hat{p}(k+1\,|\,k)$ of the state "p" at k+1 instant, as follows:

$$\hat{p}(k+1\,|\,k) = [I - K(k)C(k)]\hat{p}(k\,|\,k) + K(k)y(k)$$

where:

$$K(k) = S(k)C(k)^T\left[C(k)S(k)C(k)^T + R(k)\right]^{-1}$$
$$S(k+1) = S(k) - S(k)C(k)^T\left[C(k)S(k)C(k)^T + R(k)\right]^{-1}C(k)S(k) + Q(k)$$
$$R(k) = E[v(k)^2]$$
$$Q(k) = E[w(k)w(k)^T]$$
$$E[p(0)] = \bar{p}(0)$$
$$S(0) = E[(p(0) - \bar{p}(0))(p(0) - \bar{p}(0))^T]$$

This estimation is based upon all the previous values assumed by the vector p. Such approach is particularly useful for on-line identification of the parameters affecting the process. In the present work the above-mentioned parameters have been obtained using an apposite software tool based upon a Labview and MatLab scripts.

Details of the test conducted

In order to calculate the parameters p_i, using Kalman Filter, it is necessary to conduct a sequence of tests that permits to record data points for a subsequent elaboration. For achieving a good estimation for parameters under investigation, several experimental tests have to be conducted in different operative conditions, varying the water inlet temperature and executing the tests with variable solar irradiance levels.

Moreover, it is necessary that the collector operates in a wide range of temperature. For this reason the temperature at the inlet of collector was controlled, generating a linear heating ramp from 20 to 80 °C followed by a period of cooling. This procedure has been repeated different times within the same day.

Comparison of different methods

Different methodologies can be adopted to characterize the thermal performance of a solar collector. In the present paper a comparative analysis amongst the following methodologies has been presented:

- Steady state linear efficiency curve [5];
- Steady state quadratic efficiency curve [1];
- QDT method [1];
- Kalman filter method.

Due to the different modalities to represent the performances of solar collector, it has been decided to utilize the useful output energy as comparison condition. The useful power is given by:

$$Q_u(k) = \Gamma(k)c_p(T_u(k) - T_i(k)) = 2\Gamma(k)c_p(\overline{T_m}(k) - \overline{T_i}(k))$$

from which the useful energy is expressed as:

$$E_u = \sum_{k=1}^{n} Q_u(k) \cdot T_c$$

Analysis of the results obtained

The subsequent table shows the results obtained from various methods of calculations of the useful energy drawn from the collector. The table refers to the observation recorded on a total period of 3 days. The percentage error is estimated with reference to the values measured experimentally.

From the results obtained the following conclusions can be drawn:

- despite the error affecting the estimation of the useful energy seems to be comparable to other methods, the Kalman filter, as already mentioned, has certainly different advantages;
- however, it is to be noted that, due to the limited experimental dataset, presently it is not possible to outline a definitive conclusion.

For this reason, more experiments have been planned and final results will be presented in subsequent communications.

	Day #1		Day #2		Day #3	
	Energy output [MJ]	Error (%)	Energy output [MJ]	Error (%)	Energy output [MJ]	Error (%)
Measured	12,55	-	11,79	-	9,83	-
Stady-state linear efficiency curve	12,84	2,29	11,33	3,90	9,7	1,30
Stady-state quadratic efficiency curve	12,92	2,93	11,51	2,41	9,84	0,06
QDT Method	12,18	2,92	11,25	4,58	9,69	3,92
Kalman Filter	12,14	3,26	12,04	2,17	9,96	1,38

Nomenclature

c_p specific heat (J/ kg °C)
G_{dir} direct radiation (W/m2)
G_{diff}: diffused radiation (W/m2)
k k^{th} sampling instant
p parameters vector from discrete equation
Q_u useful power available from the collector (W)
T_a ambient temperature (°C)
T_i inlet temperature to the collector (°C) - $\overline{T_i} = T_i - T_a$
T_m average temperature of the collector (°C) - $\overline{T_m} = T_m - T_a$
T_u outlet temperature of the collector (°C)
u input vector
y output vector
Γ flow rate of heat transfer fluid (kg/sec)
θ incidence angle of radiation

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Optimised Absorbers for Solar-Thermal Collectors – CFD–Simulations of Volumetric Absorbers

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Introduction

State of the art solar-thermal absorbers are based on the sheet-pipe design with different layouts of piping. An alternative are so-called volumetric absorbers with a greater area for heat transfer between the irradiation absorbing sheet and the heat carrier. Fig. 1 shows the principle of both designs and in [1] weaknesses of the sheet-pipe absorber are presented.

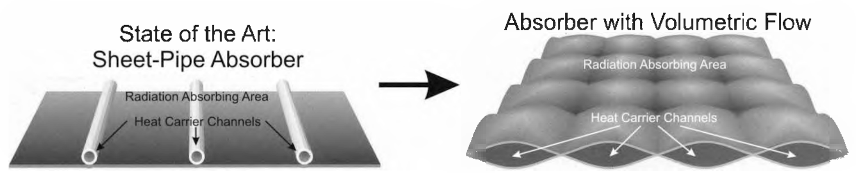

Fig. 1: Sheet-Pipe Absorber and Volumetric Absorber (pictures taken from [2])

Volumetric absorbers, however, are still in their concept phase, as fluid flow and thermodynamic properties have not yet been investigated in the necessary depth. Equal flow distribution in each riser channel as well as a low pressure loss over the whole absorber is very important. Both properties influence the operating performance and the possibility to connect more collectors in series respectively. Due to unusual branching in the channel system analytical calculations cannot be applied as friction factors for these geometries are not available. Therefore, numerical simulations need to be established to investigate flow distribution, pressure loss and in a later stage thermal properties.

Due to the complex simulation process it is not possible to carry out optimisation runs in a fast and simply way by changing the geometry dynamically. Every optimisation step needs a new mesh and simulation run, containing the changes applied to the geometry based on information of previous runs.

In any case, the flow in wide and interconnected channels has to be equally distributed to avoid regions with low fluid velocities or even dead water zones. These zones reduce the absorber efficiency significantly and cause high temperatures that cannot be transferred by convection due to the low or missing mass flux.

Subsequent to the optimisation phase further simulations and calculations will be carried out to determine the thermal efficiency of the absorber.

Computational Fluid Dynamic Simulations

Since the numerical simulations are based on models designed by CAD, each geometry has to be transferred to the simulation environment, meshed and applied with boundaries. Different ways are available for this process, as Fig. 2 shows. Due to the CAD exchange formats and their inaccuracies, errors in the geometry can occur. Hence, a geometry 'repair' has to be done in the pre-processor. Errors like no coincident endpoints, overlapping or unclosed surfaces are revised. The meshing process is then based on the 'cleaned' surface geometry, which is the basis for the 3D fluid mesh. After mesh creation, the boundary conditions have to be applied to define the properties of the fluid domain. The following settings and boundary conditions are chosen in the simulated models:

- laminar fluid simulation,
- gravity acts perpendicular to absorber surface,
- constant temperature: 298 K,
- fluid: water,
- one outlet boundary condition,
- one inlet boundary condition with different velocities applied.

State of the Art: Header-Riser Absorber

The simulation phase in the project was started with the investigation of the header-riser absorber to study the meshing process and to compare simulation results with measurements as well as analytical calculations and literature values respectively. Fig. 3 illustrates the meshed branch connection between header and riser pipe, which is the basis for further mesh processes and which was created by automatic meshing. Each section of the branch is extruded to form pipes between the branches. By copying the branch as well as the pipes the whole header-riser absorber is set up with constant mesh quality. Finally the previously introduced boundary conditions are applied.

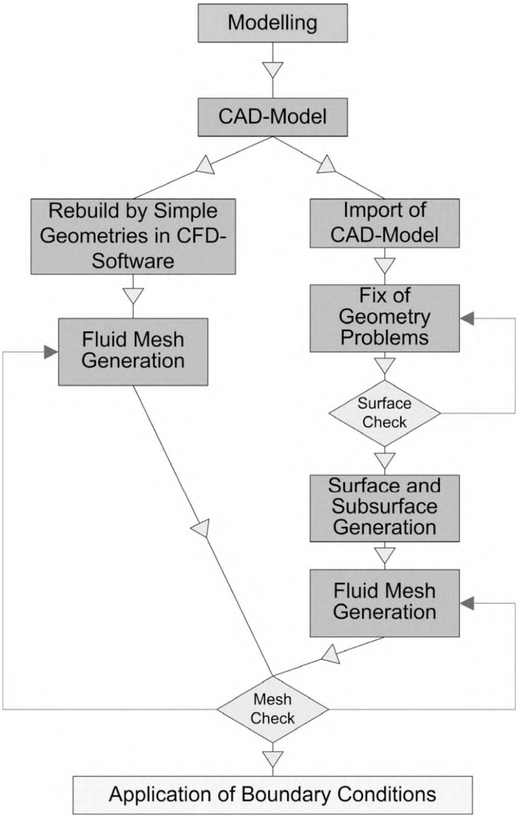

Fig. 2: Mesh Creation Process

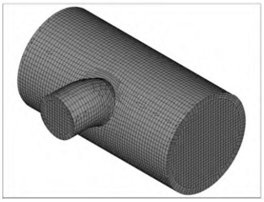

Fig. 3: Meshed Branch of a Header-Riser Absorber

- In the following simulation results for a header-riser absorber and a comparison with measurement data are explained. Fig. 4 shows the measured and simulated pressure drop for a header-riser absorber with a divided distribution header and Antifrogen N as fluid. A difference between measured and simulated pressure loss of up to 10% at high inlet velocities is shown. Although, the deviation is quite small there are differences between the real absorber and the simulated model that explain the remaining deviation:

- The riser pipes are flushed with the inner wall of the header-risers in case of the simulation model.
- Inaccuracies of the manufacturing processes are not modelled, e.g. sharp edges, residue of soldering material, etc...
- The simulations are carried out assuming laminar flow. [3] states, that the transition from laminar to turbulent flow is smooth and can only be considered as turbulent flow at Reynolds number of greater than 10^4 for circular pipes. Also [4] mentions just a slight turbulent flow in the branch connections, while a constant laminar flow can be expected in the riser pipes.

The assumption of laminar flow leads to good agreement with measurement data even in case of higher fluid velocities where turbulent effects, especially caused by manufacturing inaccuracies, are expected to become more evident.

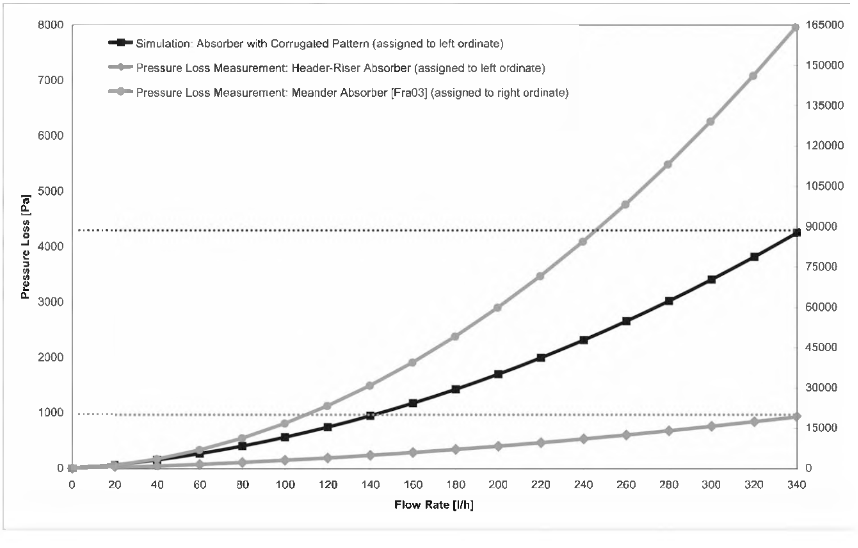

Fig. 4: Pressure Loss of a Splitted Header-Riser Absorber (Simulation/Measurement [5])

Fig. 5 illustrates the flow distribution in the riser pipes at a flow rate of 1.3 l/min. Each flow rate in the riser pipe is normalised to the flow rate at the inlet. Although all flow passages have the same length no equal flow distribution occurs. This is caused by the branch connections as they significantly influence the pressure loss of a flow passage. Along the header pipes different pressure losses occur at the branch connections as each branch has different velocity ratios. Furthermore, the friction factors are different at dividing and collecting branch connections in the upper and lower header.

The simulated flow distribution for the Header-Riser Absorber is in good agreement with [4], where graphs from experiment and piping calculations are presented.

Volumetric Concept

The volumetric absorber consists of many more riser ducts than a state-of-the-art absorber that is why the inlet area has to be designed well for equal flow distribution. Fig. 6 shows the flow distribution for a volumetric absorber at two different sections and an inlet flow rate of 1.3 l/min. The first sections show no equal distribution due to the inlet area and the flow development. Section "Group_19" with a distance of 492.5 mm to the inlet approaches the deviation of header-riser absorbers at higher inlet flow rates. Further changes in the channel design are currently carried out to achieve a better flow distribution even closer to the inlet channel. At "Group_20" in the middle of the absorber the maximum deviation amounts to 12% which is superior to state-of-the-art absorbers. Due to the uniform cross section of all ducts in a group, the outer ducts show excessive deviations. In a further optimisation process these ducts will be changed to adjust them with the inner ducts.

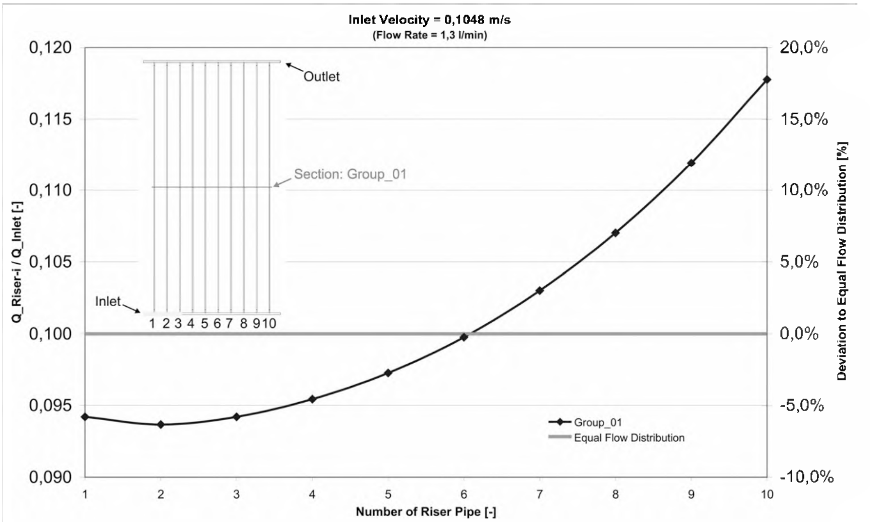

Fig. 5: Flow Distribution of a Header-Riser Absorber

Further Work

Due to the good results obtained from the simulations on the header-riser absorber further optimisation runs are carried out on the volumetric absorber designs. The first phase is nearly finished and contains the improvement of the flow distribution as well as the inlet area. The second step will be based on the optimised geometry and includes thermal simulations to calculate the collector efficiency factor. Furthermore, prototypes will be built and tested on the solar simulator at *Ingolstadt University of Applied Sciences* in a third step. Finally, simulation and measurement data will be compared to evaluate the simulation procedures.

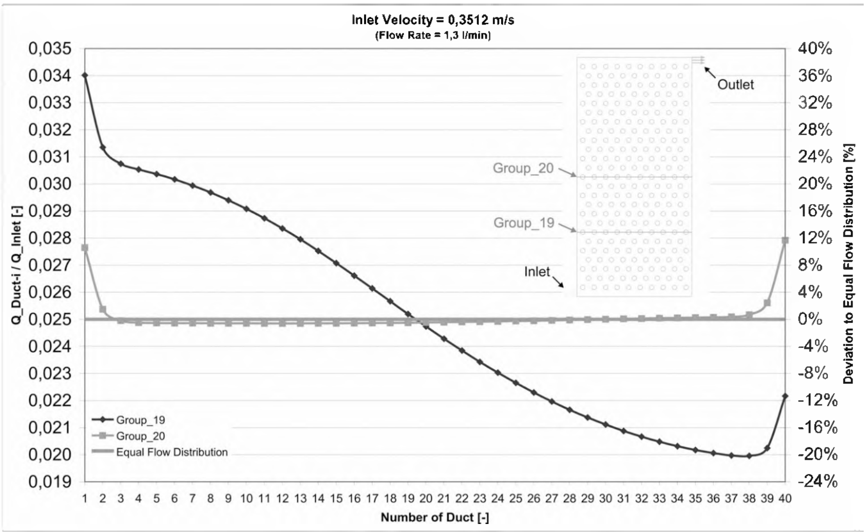

Fig. 6: Flow Distribution of a Header-Riser Absorber

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Alumina and copper oxides deposited by SPD as matrixes for cermet materials

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Introduction

Cermets, ceramic-metallic composites, have been extensively investigated for application as solar selective coatings due to their excellent optical properties. They consist of fine metal particles embedded in a ceramic matrix. The ceramic matrix role is to increase the absorption coefficient (α>0.9) and the metallic particles to decrease the thermal emittance (ε<0.1). The deposition technique for these coatings should be simple, inexpensive, and the overall process must be energy effective, thus making it feasible for industrial applications.

Due to their properties (good optical properties, good adhesion to metal surfaces, thermal and chemical stability), cooper oxide and aluminium oxide are promising candidates for a cermet matrix. The ceramic matrix (Al_2O_3 and CuO_x) morphology has an important role in designed cermet materials with optimum selective properties. A porous material is required in order to infiltrate the metal particles into the pores. The matrix porosity is controlled by varying the deposition parameters and/or by the presence of the complexing agents into the spraying solution.

Various deposition techniques have been reported for Al_2O_3 and CuO_x thin films preparation (e.g. chemical vapour deposition [1], electrochemical deposition [2], spray pyrolysis deposition (SPD) [3]), each preparation method providing different advantages. The SPD technique is an attractive method because it's low cost, simple and offers the possibility of depositing large area of thin films.

The paper presents the synthesis and preliminary characterization of two different cermet matrixes based on Al_2O_3 and CuO_x films deposited by SPD, onto microscopic glass substrates at temperatures varying from 150 °C to 300 °C. The glass substrate was chosen as reference for determining the optimum deposition conditions. The results will be applied to the metallic substrates (aluminum and cooper). The influence of the precursor solution composition and deposition parameters on the optical properties of the obtained films has been studied.

EXPERIMENTAL

Thin films of aluminum oxide and copper oxides were deposited by SPD onto microscopic glass substrate from aqueous-ethanolic solutions (W:Et = 1:1) of $AlCl_3 \cdot 6H_2O$ 96% (Reactivul Bucuresti) and aqueous solutions of $(CH_3COOH)_2Cu$ (Merck). The precursors' solutions concentration was varied from 0.01 M to 0.15 M. In order to control the morphology of the Al_2O_3 layers, Acetyl Acetone (AcAc, 99%, Sigma Aldrich) was added in spraying solutions.

The substrates (1.5 cm x 3 cm pieces of microscopic glass, Heinz Herenz) were cleaned before each deposition in ultrasonic bath with ethanol. The substrate temperature (T) during deposition was varied from 200 to 300 °C. Air was used as carrier gas at a pressure 1.4 bar. The deposition was done in open atmosphere, at a spraying angle of 45° inclination. The distance from the nozzle to heated substrate was 20 cm and the spraying sequences number was 30, with a break between two pulses of 30 seconds.

The structure topography of films was studied by Atomic Force Spectroscopy (AFM/STM, NTEGRA Probe Nanolaboratory) and the film composition was determined by X-Ray Diffraction (XRD, Bruker-AXS D8 Advance) using CuK_α radiation. The layers optical properties (α) were tested via UV-VIS (UV-VIS Lambda 25 Perkin Elmer).

RESULTS AND DISCUSSION

The structural and optical properties of alumina and copper oxides layers, deposited via spray pyrolysis technique, can be tailored by modifying precursors' solution composition (precursor concentration, type of solvent, complexing agent) and deposition parameters (substrate temperature, spraying sequences number).

One of the main optical properties required for a cermet matrix is the absorption coefficient, which was calculated from UV-VIS spectra, as the ratio between absorbed radiation and incoming solar radiation, on a wavelength domain of 0.29–1.1 µm. The solar spectrum, I_{sol}, is defined according to the 1.5 air mass standard [4].

The influence of the precursors' solutions composition and deposition parameters on optical properties of tested layers is presented in Table 1.

At constant temperatures (T = 300 °C for Al_2O_3 layers; T = 200–300 °C for CuO_x), α increases with the spraying solution concentration; this behaviour can be explained by the fact that, the higher the concentration is, the higher the film thicknesses is, therefore the quantity of the absorbed/stored energy is higher. Good results are recorded for sample Cu 4 (CuO_x), corresponding to the concentration 0.10 M, and for Al 9-2, deposited from a precursor solution concentration of 0.15 M. This can be explained considering that increasing the deposition duration, the by-products are eliminated (H_2O or HCl from AlO(OH) or AlOCl).

In case of CuO_x layers, the substrate temperature has a significant influence to the optical properties. At higher temperatures, an amount of the precursors' solution reacts above the substrate. This is correlated with lower values of the film thickness. For alumina films, the influence of the substrate temperature on α value is less significant, in the investigated domain.

The annealing process increases the CuO_x layers absorption coefficient. During this treatment, volatile by-products are eliminated and/or advanced ordering in the crystalline lattice may occur due to the passivation of the oxygen vacancy. As the temperature increases, the aggregates size is increasing along with larger pores formation.

Sample	c_{AlCl_3} [mol/L]	$c_{(CH_3COO)_2Cu}$ [mol/L]	Solvent	Complexing agent	T [ºC]	α
Al 1	0.1	-	$H_2O:Et_{(V)}$ =1:1	-	200	0.05
Al 2	0.1	-		-	250	0 21
Al 3	0.1	-		-	300	0 10
Al 4	0.1	-		AcAc	300	0.09
Al 5	0.15	-		-	200	0 03
Al 6	0.15	-		-	250	0 15
Al 7	0.15	-		-	300	0 17
Al 8	0.15	-		AcAc	250	0.18
Al 9	0.15	-		AcAc	300	0 19
Al 9-2*	0.15	-		AcAc	300	0 21
Cu 1	-	0 01	H_2O		200	0 32
Cu 1a**	-	0.01			200	0.40
Cu 2	-	0 01			250	0 26
Cu 2a**	-	0 01			250	0 28
Cu 3	-	0.01			300	0.26
Cu 3a**	-	0.01			300	0.32
Cu 4	-	0 1			200	0 90
Cu 4a**	-	0 1			200	0 98
Cu 5	-	0.1			250	0.82
Cu 5a**	-	0 1			250	0 81
Cu 6	-	0 1			300	0 82
Cu 6a**	-	0 1			300	0 96

Table 1 The deposition condition for the matrixes
** The number of spraying sequences is 60*
*** The sample was annealed for 3 hours, at 400 °C, in air*

The XRD diagrams for Al_2O_3 samples (Fig. 1) show the presence of by-products with crystalline structures: AlO(OH) and AlOCl. Still, the predominant phase is amorphous alumina, according to literature [5] and the AFM images (Fig. 3) confirm this observation. The XRD spectra recorded for CuO_x (Fig. 2) show the presence of crystalline CuO as predominant phase, which has a positive influence on α [6].

Depending on the deposition parameters, different morphologies were obtained, Fig. 3 and 4. Alumina exhibits glassy structure with large pores, while CuO_x was deposited in crystalline thin films. Long deposition duration along with higher deposition temperatures results in porous matrix structures. The explanation is also linked with higher nucleation rates, in the primary deposition steps, which enable the fast formation of a high number of crystallization points.

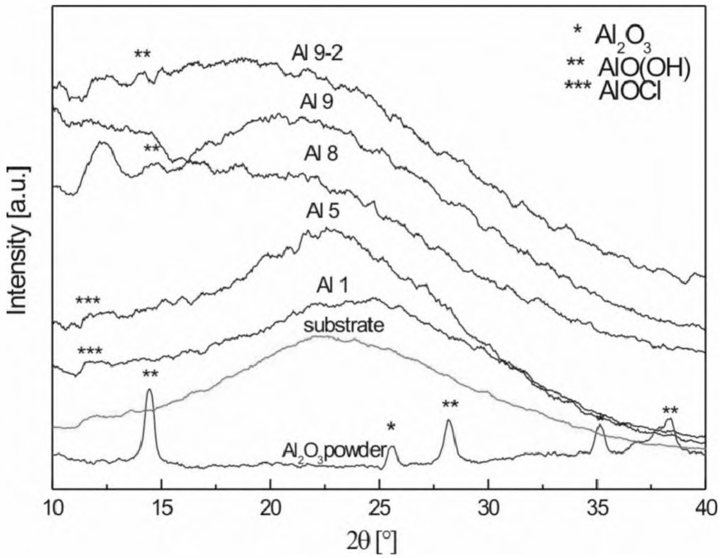

Fig. 1 XRD for Al_2O_3 samples

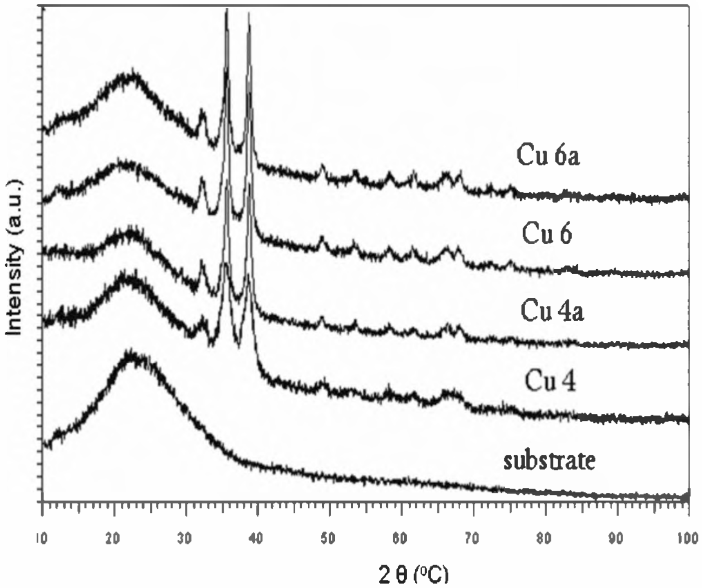

Fig. 2 XRD for CuO_x samples

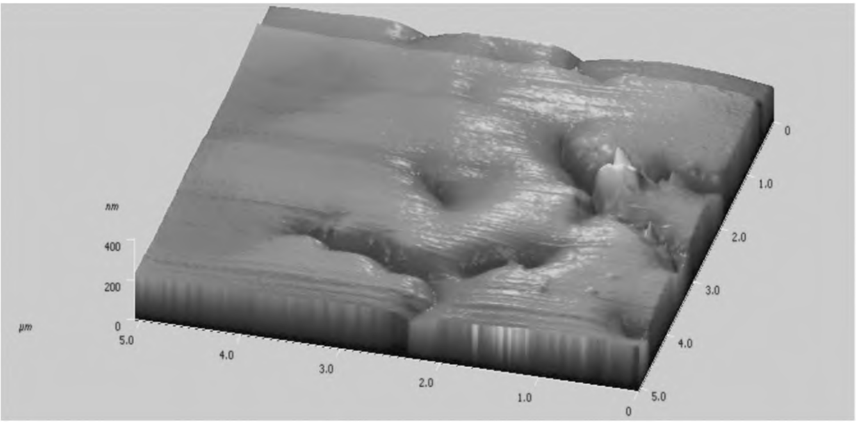

Fig. 3: AFM for sample Al 10

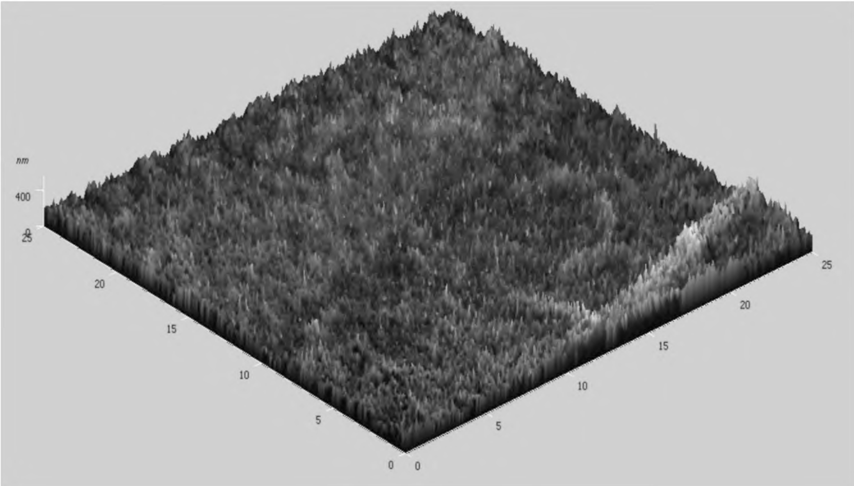

Fig. 4: AFM image for sample Cu 6

Conclusions

Thin films of Al_2O_3 and CuO_x deposited by SPD on glass substrate, have been optimized by varying the deposition temperature, precursor's concentration and annealing process. The absorption coefficient increases at moderate temperatures and higher precursors' solution concentration. The annealing process positively affects the absorption coefficient due to the elimination of by-products and advanced reordering in the crystalline lattice.

Structural analyses have shown that alumina layers contain amorphous Al_2O_3 and traces of crystalline by- products, while CuO with crystalline structure is the predominant phase in CuO_x films. The layers deposited by using complexing agents showed a more porous structure.

Further studies will focus on increasing the optical properties by metal infiltration and anti-reflexive layer deposition using the same technique.

Acknowledgments

The research work was supported by the CEEX program: MATSOL 277/2006.

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Comparison of Performance for Evacuated Tube and Flat Plate Solar Collectors for Domestic Hot Water Applications in Northerly Climates

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Introduction

Thermomax research and development are conducting a yearlong study to compare the performance of traditional Flat-Plate Collectors (FPC) against Evacuated Tube Collectors (ETC) in a north European climate. Both collector types were connected to identical system set-ups and exposed to identical environmental conditions. Data from the collectors, tanks, control system and weather station were monitored at intervals of 10 seconds. This report highlights the initial findings of the study from January to March 2007.

Experimental Set-up

The two solar thermal collector systems FPC and ETC were installed side by side and connected to independent unvented storage tanks with 250 litres capacity. Temperature differential solar control units with identical setups were used to monitor the FPC and ETC solar thermal collectors. Fig. 1 shows the collectors installed on the Thermomax outside test platform. They were mounted due south with slopes of 45°, located at 54° 38.55 N, 5° 40.48 W in Bangor, Northern Ireland.

Table 1 shows the technical data for each collector. Fig. 2 shows a schematic of the full test system. For these initial tests the collectors were simply allowed to heat the tanks based on the controller function. No additional heating via the primary coil or the auxiliary heat source was supplied. This allowed any errors in the system to be corrected and allowed the performance of the collectors to be assessed over a range of temperatures with no thermoclines within the tank.

The collectors and tanks were fully instrumented with temperature sensors and flowmeters to allow the calculation of energy transfer. Water was the working fluid within the system loops, in preference to a water/glycol mix for installation modification reasons.

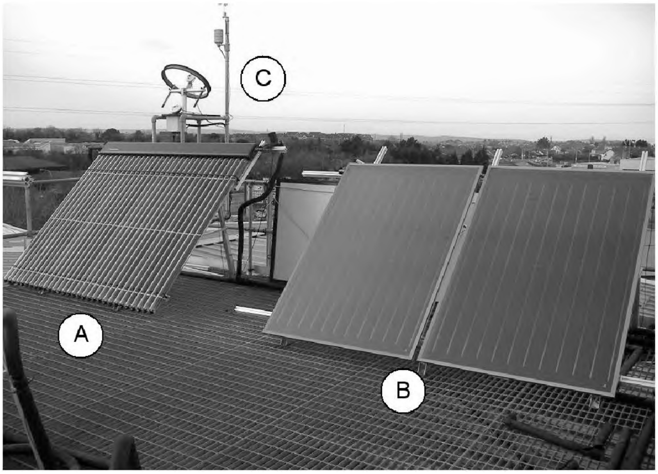


Fig. 1.

Shown here are the side-by-side installations for ETC and FPC collectors.

Markers A, B and C Indicate:

A) ETC Collector
B) FPC Collector
C) Weather Station

	ETC 30 Tube Array	FPC 3.6m^2
Absorber Area (m^2)	**3.021**	**3.64**
Aperture Area (m^2)	**3.229**	**3.84**
Gross Area (m^2)	**4.265**	**4.17**
Fluid Volume (litres)	**1.8**	**2.4**
Weight (kg)	**75**	**74**
η_0 (-)	**0.792**	**0.78**
k_1(Wm^{-2}K^{-1})	**1.25**	**3.796**
k_2(Wm^{-2}K^{-2})	**0.008**	**0.013**

Table 1: Techincal data for each collect respectively

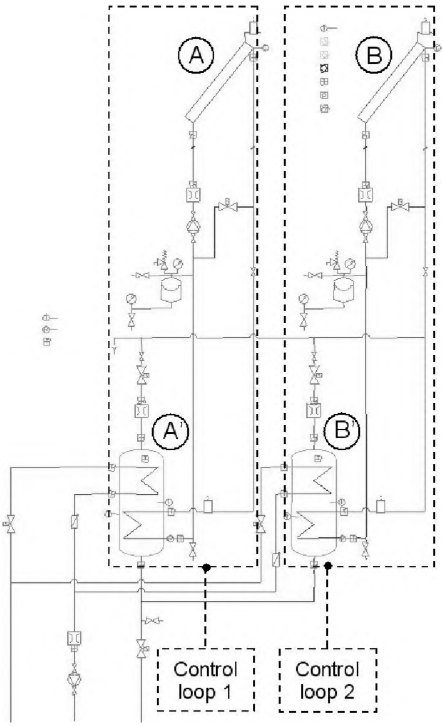


Fig. 2.

This illustration shows the schematic for the hydraulic system for each collector.

The systems were independent, apart for a common main water supply to the tanks. The auxiliary heating source was not used during the initial test of the system.

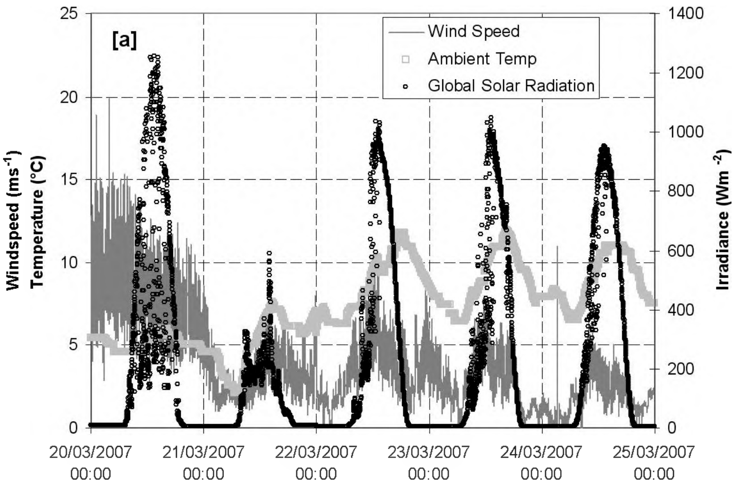
Markers
A, A' and B, B'
Indicate:

A) ETC Collector
A') ETC Storage
B) FPC Collector
B') FPC Storage

The control loops monitored the collector temperatures, tank coil temperatures, tank temperature, flow rate and system pressure.

The weather station monitored the global and diffuse irradiance, ambient temperature, wind speed and humidity.

Result and Discussion



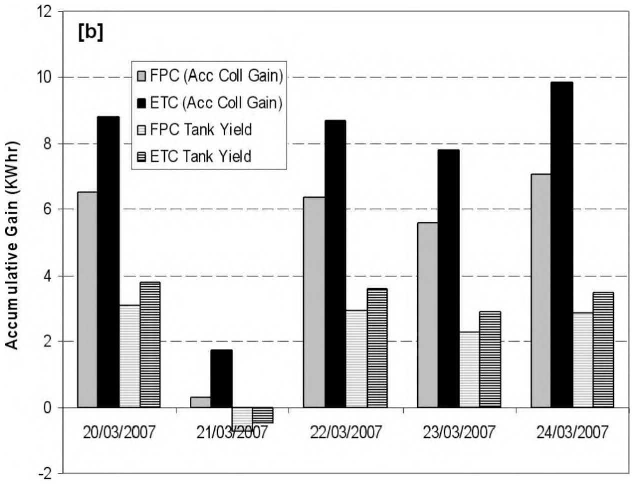


Fig. 3: [a] Shows the weather conditions for collectors under test, [b] shows the absolute values of accumulative gain and tank yields for the FPC and ETC collectors respectively

The results shown were recorded for the initials days of data collection immediately following installation and instrumentation. Five days data are shown in Fig. 3b, starting in late March. The environment conditions were ideal for comparison testing being bright (Peak 950 Wm^{-2}) and cool (5–12°C) with moderate wind speeds (5–10 ms^{-1}). The results were normalise to unit area values and summarised in Table 2.

	Collector Gain			Tank Yields		
	ETC	FPC	ETC/FPC	ETC	FPC	ETC/FPC
Day	$kWhm^{-2}$	$kWhm^{-2}$	-	$kWhm^{-2}$	$kWhm^{-2}$	-
20/03/07	2.73	1.71	1.59	1.21	0.81	1.49
21/03/07	0.56	0.05	11.11	-0.07	-0.10	0.7
22/03/07	2.76	1.67	1.65	1.18	0.78	1.51
23/03/07	2.46	1.46	1.68	0.90	0.57	1.58
24/03/07	3.07	1.82	1.69	1.16	0.73	1.59

Table 2: Collector Gain, Tank Yields and Comparison based on Aperture Area

Based of these initial results shown in Table 2, the Evacuated Tube collector's performance had gains of approximately 1.65 times that of the Flat Plate on bright cool days. The contribution to the tank for the Evacuated Tube was approximately 1.55 times that of the Flat Plate under the same conditions.

On duller days such as 21/03/07 the ETC had ~11 times the collector gain of the FPC. However as the solar pump only functioned for a short period on this day (approx 30 mins at 14.00) the most interesting point of note is the tank yields. The FPC lost 0.10 $kWhm^{-2}$ from the tank whereas ETC lost 0.07 $kWhm^{-2}$. This was most probably a result of increased rates of thermosyphoning from tank to collector due to the larger thermal losses of the FPC to the environment. However at this stage it is too early to say but the matter warrants further investigation.

Conclusion

Initial results indicate that in cool bright conditions an evacuated tube collector will have a greater performance than a flat plate collector given identical set-ups. Based on unit areas the collector gain and thermal yield of the evacuated tube collector will out perform the flat plate collector by approximately 1.6 times.

Future work

The author realises that these results were based on a small data set, this study will continue for a full year in order to build up statistical rigor. An extension of the calculations will be made to include real-time analysis of efficiencies, gains and thermal yields. A set-up modification will also simulate draw-off profiles and auxiliary heating sources.

The sun as the main energy source for space heating: from vision to reality

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Introduction

One of the main difficulties with the use of solar heating systems is the fact that present technology (unless used in specially built 'solar houses') only enables solar heating as an auxiliary system. The larger part of the required heat still has to be obtained from exhaustible fossil fuels or from biomass, which is also limited in supply. One of the main goals in the solar thermal industry is therefore to develop systems in which this relation is inverted: to cover the greater part up to as much as 100% of the energy needs from solar energy and only use conventional energy sources for the remaining portion.

The fundamental problem here is that multiple opposing factors occur at the same time: in winter, when the need for heat is greatest, both irradiance and the outdoor temperature are at their lowest. Apart from there being less irradiance, this also results in significantly reduced collector efficiencies which cuts the solar yields even further.

Since 2003 Consolar has been working on a completely new solar energy system that overcomes these problems to make the vision of solar heating a reality.

Limits of solar and heat pump technology

Due to supply uncertainties and dramatic increases in energy prices for fossil fuels, the use of electric heat pumps has seen rapid growth. These pumps are powered by electricity, which means that there is only a primary energy saving if the seasonal performance factor (SPF) for heating and hot water is significantly higher than 3. Great progress has been made here in recent years. However, ground heat exchangers or borehole heat exchangers need to be installed for efficient heat pumps. This is a significant cost factor that so far has limited their use. The cheaper and easier-to-install alternative – air-to-air heat pumps – have the disadvantage of significantly worse coefficients of performance (COP) and/or higher annual electricity consumption. This is due to the fact that the times when the outdoor temperature is lowest and hence the heat pump's electricity requirements are highest are also the times with the greatest need for heating.

Solar thermal systems are usually operated in parallel to the heat pump. As a result, operation is not optimal neither for the heat pump nor for the collector since both components run at an increased temperature level. Besides, coupling the two systems, involves the expense of two systems.

SOLAERA: solar heat pump system from Consolar

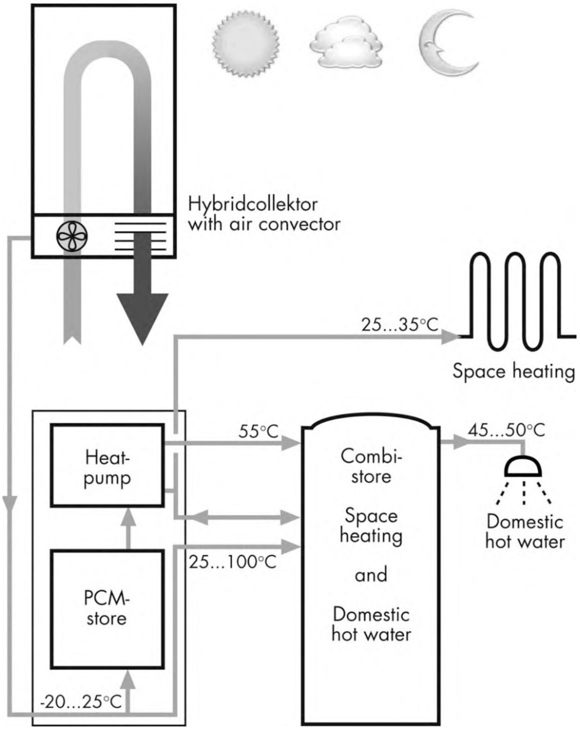

Fig. 1: Components and energy flows in the SOLAERA system.

As part of a development project sponsored by the German Environmental Foundation (DBU) in collaboration with Grammer Solar and Delzer Kybernetik, Consolar has developed a solar heat pump system that enables 100% coverage of heating requirements in a low-energy house (hot water and heating consumption up to 10 MWh per year[1], low temperature heating) without additional borehole heat exchangers. The SOLAERA system (patented) comprises a solar thermal system for hot water and space heating that is coupled to a heat pump.

Through connection in series to a heat pump and a water/ice storage medium, a collector surface area of 20–25 m² achieves an energy saving of approx. 85%[2] or even more with larger collectors. If it is assumed that the electricity required to power the heat pump is generated with a power station efficiency of 33%, the primary energy saving compared to oil or gas heating (90% efficiency) is still 60%.

In the SOLAERA solar heating system the heat pump is used to take heat from the heat exchange medium even if the sun heats it only by a few degrees Celsius. The heat pump uses this energy to generate heat that can be used for heating. Consequently solar collectors can be operated in winter at very low temperatures and as a result have almost zero heat losses, i.e. maximum efficiency. The gross thermal yield of a flat-plate collector in January in South Baden (Germany), if it is operated at 10 °C instead of 50 °C, increases by approx. 90%. If it is operated without thermal losses it increases by 110%.

The system is coupled to a latent heat storage system (water/ice), in which low temperature heat with high specific heat capacity can be stored for subsequent use at night, for example. For a reduction in temperature of 10 K the capacity of the 320 l water/ice storage system corresponds to that of a 2500 l buffer storage tank. Owing to the low temperatures, the energy is stored loss-free. However, this on its own would not be enough to cover the heating requirements. With a solar yield of approx. 42 kWh/m² in January (60° tilt), a collector area of 52 m² and a much larger storage system would be needed to cover the heating and hot water requirements of the Stiftung Warentest reference house (2159 kWh in January). As a result, other systems that use solar collectors connected to a heat pump as a low temperature heat source usually need very large and underground storage tanks and/or larger collector areas. [/1/ /2/]

In order to ensure the supply of heat during longer periods of bad weather while still having reasonable collector sizes and storage tank volumes, the SOLAERA solar collectors are designed so that they can take heat from the ambient air – even if the sun doesn't shine.

As a result the system produces heat in any weather: usually the coldest days in winter have a clear sky, with sunshine. The solar yield from the solar collectors is then good enough for heating. On the other hand, when the sky is overcast the air temperatures are usually not extremely low. At these temperatures the heat pump can extract enough heat from the air with good efficiency.

Starting with the first warmer days in spring and lasting until autumn, the solar yields are generally sufficient to cover the complete heating requirements without using the heat pump. As a result SOLAERA uses very little electrical power during this period – almost all the required energy comes directly from the sun.

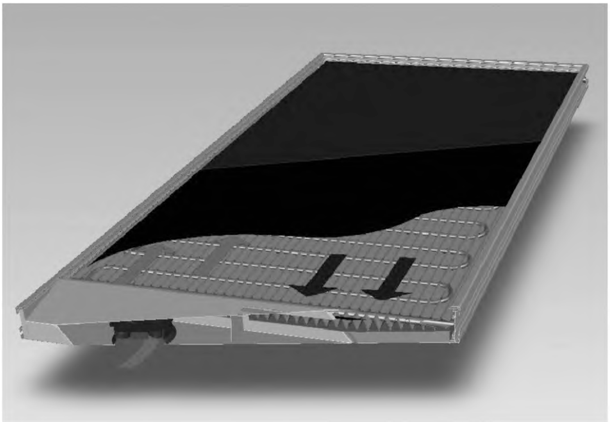

Fig. 2: SOLAERA collector – like a normal solar collector from above, below the absorber ambient air can be blown through to warm the solar liquid.

The system is designed as a compact unit: the technical components – heat pump, latent heat storage unit, valve fittings and regulator – are housed in the energy centre with a footprint of 80 x 80 cm (see Fig. 3). The system is connected to a combined storage tank having a capacity of 1000 l. Hence SOLAERA does not require excavations and although modern insulation standards need to be met, in terms of space requirements it can be used in any house.

Fig. 3: The energy centre comprises heat pump, latent heat storage unit (seen at bottom), valve fittings and controller, plus the 1000 l combined storage tank.

The main components are completely new developments (especially the collector and latent storage system), or are specially adapted (heat pump, combined storage tank).

The new control strategy that was specially developed for SOLAERA plays a key role in ensuring minimal electricity consumption.

The project partners mentioned above are now no longer involved in the project. Consolar has assumed full control of collector and controller development.

Operating experience

Consolar's first test system has been in operation since autumn 2004. In December 2006 two pilot systems for a semi-detached house went into operation. Valuable experience was gained from the installation and commissioning of the pilot systems. Much of this knowledge went into the design data for the future production components and control parameter settings. The system was installed by a 'normal' plumbing firm, revealing a number of possible installation errors which can be avoided in the production models by taking appropriate steps. One example of this is condensation and ice formation on areas without sealed insulation: the quality requirements for the insulation are higher than for a normal solar energy system, which means the installation firm has to be told about this and provided with special accessories.

The two systems were closely monitored and measured. However, it was not possible to calculate the exact energy savings in the first months: first of all the measurement systems did not fully record all the data, and secondly, due to the work on the building various falsifying factors were present such as scaffolding (shading on the collectors and at times on the irradiance sensor too), uninsulated areas such as storage tank connections and hot water pipes, no record of the hot water consumption initially, etc.

Fig. 4: Semi-detached house with the first two SOLAERA pilot systems during the construction phase.

A COP of 3.2 was calculated for the heat pump for the months of January and February. A rough assessment shows that primary energy savings for the system as a whole in these two months was 26% and 34% respectively. An approximate evaluation of the impact of various error factors shows that with proper performance data and operation in the months of January and February, the primary energy savings would have been more than 50%. Of course over the year as whole this figure would be even higher.

Outlook

In 2007, SOLAERA will be installed and tested in 15 to 20 field test systems. Since the end of 2006 the collector has been redesigned and optimised. Several series of tests are conducted at the Fraunhofer ISE for this purpose.

The SOLUS combined storage tank and the water/ice storage tank are currently being tested at the ITW. Parallel to this, SOLAERA is being modelled in TRNSYS as part of a doctoral thesis in charge of ITW and Consolar. This will allow optimisation potentials to be investigated and quantified.

SOLAERA is set to be available on the market in 2008.

Literature

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[1] Value is somewhat lower than the consumption data for the 'Würzburg reference house' used by the German consumers' association Stiftung Warentest since a significant reduction can easily be achieved by using a simple heat recovery system.

[2] Data based on simulations with DK-Solar.

Solar façades on the sustainable highway maintenance building CeRN in Bursins

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Introduction

Façade integrated unglazed thermal solar collectors have recently been integrated on the highway maintenance building CeRN in Bursins near Geneva (Switzerland). It can be considered as an implementation of several criteria identified by European projects to allow future widespread of solar heating: simplification of the solar collectors, increase of architectural acceptance and reduction of solar energy cost. The described solar system fully matches nowadays contractor concepts of sustainable development.

© MINERGIE ECO building

The CeRN in Bursins has been designed as a milestone project for sustainable building in Switzerland. It is the first building to fulfil the requirements of ©MINERGIE ECO. The Swiss quality label ©MINERGIE for new and refurbished buildings emphasises on comfort of the users through high-grade building envelopes and systematic air renewal.

©MINERGIE ECO goes one step further, requiring building materials choice, with minimum grey energy content and ability to be recycled, thus limiting environmental impacts.

The building cost evaluation criteria have not been limited to the construction only, but have also taken the running and maintenance costs over a period of 40 years into account. This global approach has lead to look beyond standard solutions.

Combined solar-wood heating system

The heating demand of this low energy building is 111 MJ/m2.y. The orientation and design of the building (long zone of offices on the South side of the building) allows a good passiv solar gain and natural lighting.

For the heating system it was obvious to favour the use of renewable energy sources (solar and wood). Solar energy is covering 40% of the heating demand. The back-up heating is done with a 118 kW waste wood boiler, burning wood proceeding from the highway maintenance. The solar heat is used to feed a low temperature floor heating system during wintertime. A particular attention has been drawn on a low temperature distribution system, which has been designed to comply with a solar system.

Outside the heating period the solar system covers a considerable part of the energy demands for the domestic hot water to wash the highway maintenance vehicles.

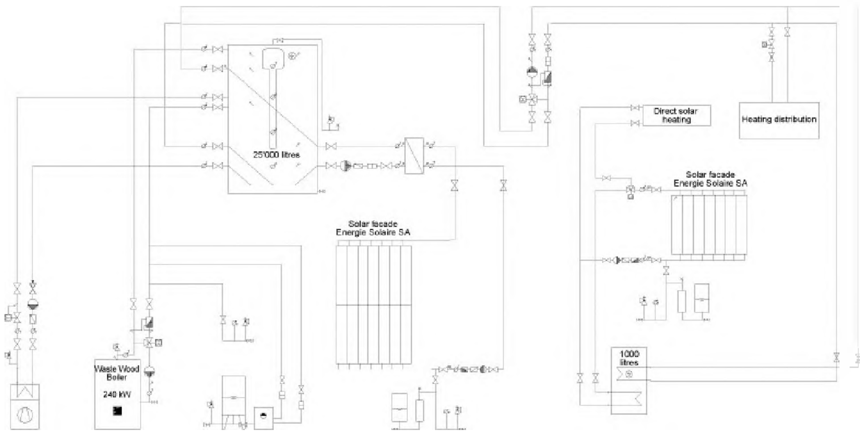
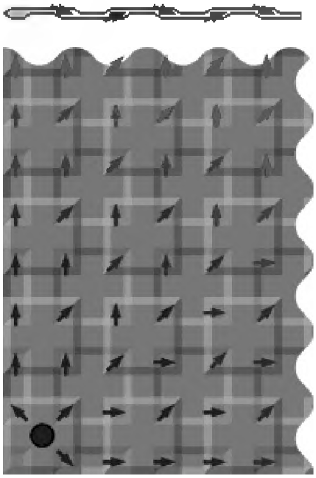


Fig.: Technical scheme of the heating system

FAÇADE WITH CLADDING OF STAINLESS STEEL SOLAR COLLECTORS



The South facing side of the CeRN in Bursins is covered with thermal solar collectors. The vertical position of the collectors gives a good compromise between solar yield and architectural integration for optimum yield during this period of the year. Used as façade element the public authority of the Canton of Vaud, the building owner, also openly wants to openly show his choice for solar heating and renewable energies.

The solar collectors on the CeRN do not only operate as solar collector. They are not an additional element on the building but are used as a construction material in the proper senses of the word, matching the economical and sustainable criteria of this project.

The solar façade consists of stainless steel absorbers from Energie Solaire SA, consisting of plane heat exchangers with full irrigation. They are composed of two stainless steel foils on which regularly spaced square bumps are stamped. Front and back sheets are seam welded on the periphery and spot welded between each bump to ensure form stability even at pressures of 3 bars. The cushion geometry of the front sheet is set off over half a pitch towards the back sheet. This ensures a uniformly spread water flow between both sheets as shown on the flow distribution drawing and section.

The selective coating (α = 0.95, ε = 0.15) on the absorbers stands outdoor weather conditions without alteration. Thus, solar panels, covered with this selective coating, can be installed without glass cover. Unlike conventional collectors available on the market, the solar radiance reaches the absorber surface without being absorbed or reflected by a glass; therefore the effect of slope and azimuth are minimised. In other words, the position of these solar collectors has a relatively low influence on its grade of efficiency. This allows a large flexibility of building integration. Inclined planes with only 5° slope, curved roofs or vertically as solar walls on façades are realisable.

Official tests and experience have shown an excellent efficiency of this absorber at relatively low temperatures or in mild climates. Under these conditions the Energie Solaire SA unglazed collectors give results equal or even superior to those of glazed collectors. Finally, unlike glazed solar collectors, the Energie Solaire unglazed collectors do not present the problem of overheating, as the stagnation temperature does not exceed 110 °C.

The solar collectors are made of stainless steel, an exciting building material, which provides an ideal combination of high strength, workability, excellent corrosion resistance and exceptional durability. It withstands the impact of aggressive climates (heavy polluted air in cities, salty air in saline atmospheres) without any damage. It is also fully recyclable. The panel size is modular in length, in order to fit easily into the architectural concept of the building. A module weighs about 10 kg/m2, which makes mounting easy.

Panel fixing and jointing mode is done with conventional aluminium profiles with EPDM joints used to fix metal cladding. Once mounted the façade forms a perfectly watertight and durable wall.

In order to keep the same aesthetic appearance on the façades, which are not facing South, a metal cladding using "dummy solar panels" with the same square bump geometry as the solar collectors from Energie Solaire S. A. have been used.

Conclusion

Solar façades on the highway maintenance building CeRN provide a good compromise between architectural integration and energy efficiency for low temperature floor heating. In order to achieve an optimum solar yield the solar absorbers used for this project are fully irrigated and have a selective coating withstanding aging under outdoor conditions without alteration. These stainless steel solar collectors plainly fulfil the criteria of sustainability brands like ©MINERGIE ECO, including durability, grey energy content and recycling.

Technical file of the building

- Location: Bursins (CH)
- Year of building construction: 2003–2007
- Year of system construction: 2003–2007
- Architects: Atelier atelier niv-o (www.nivo.ch)
- Engineering office: Keller-Burnier (Lavigny, CH)
- Solar façade surface: 590 m²
- Solar collector manufacturer: Energie Solaire S. A. (www.energie-solaire.com)

Design and performance of hybrid PV/T solar water heaters

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Brief aspects for hybrid PV/T solar collectors

Commercial photovoltaics (PV) convert, depending on the type of PV cells, 5%-15% of the incoming solar radiation into electricity, with the greater percentage converted into heat. PV modules and heat extraction units mounted together constitute the hybrid photovoltaic thermal (PV/T) solar collectors (Fig.1, left), which convert the absorbed solar radiation into electricity and heat simultaneously. The solar radiation increases the temperature of PV modules, resulting in a drop of their electrical efficiency, but their installation on horizontal roofs of buildings permits their natural cooling. In the facades and tilted roofs, cooling of PV rear surface is achieved also with circulating water of lower temperature than that of PV modules, which is heated by cooling them and resulting to keep PV electrical efficiency at a satisfactory level. The PV/T collectors present a conflict with their electrical and thermal performance. The electrical part presents higher output for lower PV operating temperatures. On the other hand, the thermal part should provide heat removal fluid (water or air) at higher temperatures in order to adapt effectively the solar thermal applications, but this results to electrical efficiency drop. The additional thermal output that is provided from PV/T systems makes them cost effective compared to separate PV and thermal units, considering that they cover together the same total aperture surface area as that of PV/T collectors. An extensive study on water [1,2,3,4] and air [1,5,6,7] heat extraction from PV modules has been performed at the University of Patras and hybrid PV/T prototypes have been investigated. Performance improvements aim to overcome some limitations in system efficient operation and to make these new solar energy devices more attractive for applications. The water type PV/T systems (PVT/WATER) are more expensive than air type PV/T systems (PVT/AIR) and can be effectively used all seasons, mainly in low latitude countries, as water from mains is usually under 20 °C. The PVT/WATER systems can be installed on horizontal or tilted roof (Fig. 1, right) of buildings, or also on their facades, depending on building architecture. In this paper we briefly present the design and performance of the studied hybrid PVT/WATER systems in our laboratory. The systems have been designed and tested outdoors, while modeling results have been extracted, aiming to the optimization of system design and operation. These PV/T collectors can provide hot water and electricity in the domestic, agriculture and industrial sectors. Regarding small size PVT/WATER systems they can be applied to one family houses, multiflat residential buildings, small hotels, etc. These devices can be used alternatively to the thermosiphonic and the ICS solar water heaters, mainly in stand-alone and mini-grid application of photovoltaics. To increase system energy output we have studied the application of booster diffuse reflectors [1,2], which increase the solar radiation on PV module aperture surface and overcome the reduction of the electrical output due to the optical losses from the second glazing. In this paper, some aspects and results give a figure of system design and performance in laboratory scale operation.

PV/T SYSTEM DESIGN AND OPERATION

The hybrid PV/T solar water heaters can be effectively used for domestic water and space heating and other applications, contributing also to the electrical consumption of the buildings. The investigated PVT/WATER models consist of silicon PV modules and the heat extraction unit is a metallic sheet with pipes for the water circulation, in order to avoid the direct contact of water with the PV rear surface (Fig.1, left). This heat exchanger element is in thermal contact with the PV module rear surface and is thermally insulated to the ambient from the rear side and the panel edges.

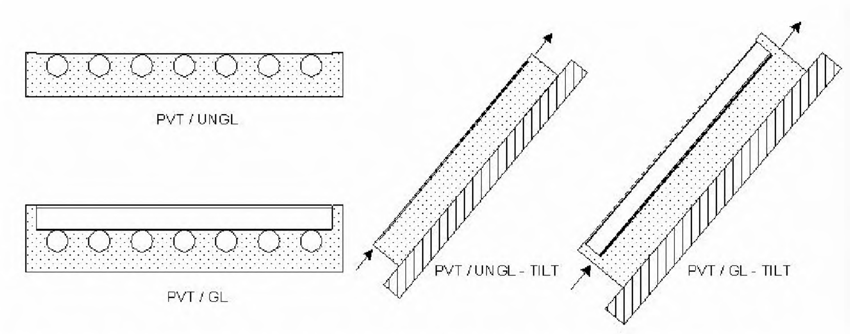

Fig. 1: Cross section of the studied PV/T models (left) and their tilted roof installation (right)

In case of using PV/T systems without additional glazing (PVT/UNGL), they provide satisfactory electrical output (depending on the operating conditions), but the thermal efficiency is reduced for higher operating temperatures due to the increased thermal losses from the PV module front surface. The addition of glazing (PVT/GL) increases the thermal efficiency for a wider range of operating temperatures, but the additional optical losses reduce the electrical output of the PV modules. Hybrid PV/T systems can provide electrical and thermal energy, thus achieving a higher energy conversion rate of the absorbed solar radiation. We tested outdoors PV/T prototypes consisted of pc-Si PV modules and heat exchanger of copper sheet with copper pipes, for two system types (PVT/UNGL and PVT/GL). We used commercial PV modules, which give about 8%-15% efficiency, depending on the operating temperature and the use or not of additional glazing. During the experiments the generated electricity was transmitted to a load, simulating real system operation. The steady state tests were performed outdoors and the results for the collector obtained thermal efficiency are shown in Fig. 2. The glazed PV/T collector presents remarkably higher thermal output than the unglazed PV/T collector, but the electrical output of it is reduced due to optical losses. Apart of the steady state operation, both PVT/WATER collectors were connected with a water storage tank for daily operation with forced (with pump) and natural (thermosiphonic) water flow. In Fig.3 we present a daily profile for the natural water flow, showing the variation of the mean temperature of PV module (T_{PV}), circulating water (T_m) and of the water in the storage tank (T_{ST}), the ambient temperature (T_a), the incoming solar radiation (G) and the wind speed (V_W). The systems were also tested with booster diffuse reflectors, which are fixed for the case of the horizontal building roof system installation [1,2], but they can be adjusted in the case of small size units. The contribution of the reflectors is estimated positive in all cases, considering the energy output increase and their low additional cost.

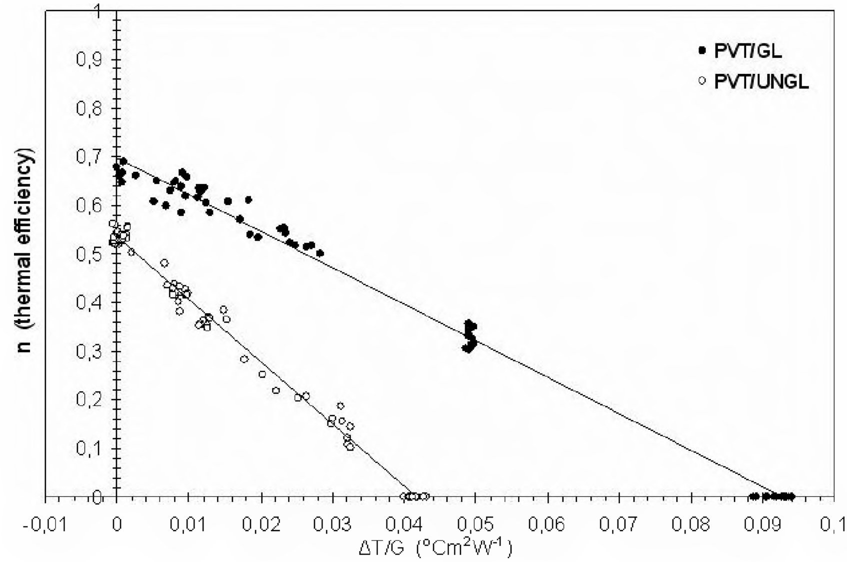

Fig. 2: Steady state thermal efficiency results of the studied PV/T models

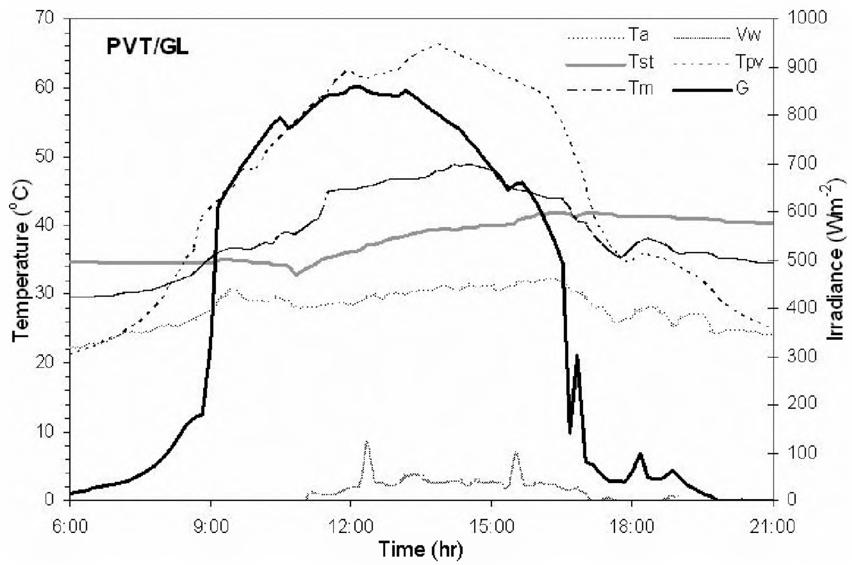

Fig. 3: Daily profile of temperatures, solar radiation and wind speed for the PVT/GL system with natural water flow operation

The PV/T collectors were also modeled to study the effect of several parameters to system performance. In Fig.4 we give a figure of the glazed PV/T collector validation for the steady state operation of it, which is estimated satisfactory. By the developed theoretical model we can determine the optimum system design regarding collector application requirements. Water-cooled PV/T systems are practical systems for water heating in the domestic and industrial sectors and previous studies [2,3,4] have shown that they reduce the pay back time of PV modules, mainly for low water temperatures. In addition, the increase of energy output from PV modules (electricity and heat) results also to PV environmental benefits by reducing the energy and CO2 pay back times, as we have observed in our studies with LCA methodology [2,5].

Conclusions

Hybrid PV/T solar water heaters have been studied in Physics Department at the University of Patras. These systems can be applied in houses and other buildings for the production of electricity and hot water and are mainly suitable for applications under high values of solar radiation and ambient temperatures. The outdoor testing and the modeling results give a figure of system performance, while previous studies show that the PV/T collectors are cost effective and of low environmental impact.

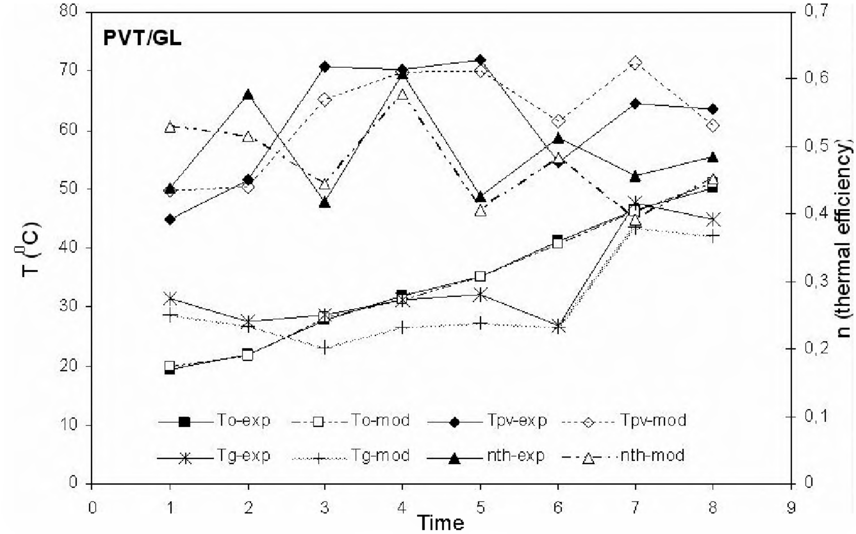

Fig. 4: Comparison of experimental (exp) and modeling (mod) results of system parameters under steady state outdoor tests of the PVT/GL collector

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Thermal Solar System with Direct Heat Storage for Space Heating and Cooling

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INTRODUCTION

In the year 2000, the Alberta Research Council Inc. (ARC) developed a thermal solar system with the ability for direct heat storage (DHS), which was designed for the purpose of space heating in residential dwellings and commercial buildings.

The DHS thermal collectors are designed to be integrated with building walls and, as a result, to accumulate the thermal energy directly into the building envelope. The wall integrated DHS collectors are also designed to fulfill the functions and requirements of façade elements. A key part of ARC's technology is the heat storage layer. This consists of phase change material (PCM) with the ability for solar radiation absorption, heat generation and thermal energy storage. During the phase change, the material absorbs or releases a significant amount of energy in the form of latent heat.

A separate part of the new concept is an implementation of DHS solar collectors on three walls of a building to maximize the solar energy gain. The three-wall solar system is especially justified in northern regions where vertical building walls are well suited for solar energy collection during winter months, which are characterized by the low position of the sun. The three-wall DHS thermal solar system with a significant, envelope integrated thermal mass is a subject of special interest because of its dual purpose. It can be used for space heating in winter and for the purpose of cooling in summer. During the past two years, the DHS solar system has been extensively tested at ARC's facilities in Edmonton, Alberta, Canada.

SOLAR ENERGY GAIN FOR THREE-WALL SYSTEM

The traditional approach is to apply solar collectors on the south-facing walls or roofs of dwellings. However, the solar gain in building space heating systems can be increased by application of the eastern and western walls as well. When developing a three-wall solar energy system concept to maximize the energy gain, the important question is finding out the potential benefit of the three-wall idea.

Solar energy collecting potential during a year, as a result of varying sun exposure time (length of day) and changed incident angle (seasons) undergoes significant variation. The regional climate is another factor having impact on available solar gain. To evaluate the three-wall solar collecting system concept a series of tests were performed.

In Fig. 1, the summary on the solar energy gain potential, for a three-wall system is presented. The solar gain for eastern and western walls are combined together. The solar gain is given in MJ per 1 m^2 of vertical, sun exposed wall surface, and the house specific energy demand, which was given for a reference, is in MJ per 1 m^2 of the house floor area. The specific energy demand per floor area for average house located in Central Canada is about 1,000 MJ/m^2/year.

The solar insolation curves as presented shows; the insolation potential at clear sky conditions and at the actual conditions (calculated as an average over a one week time period). For specific regions, knowledge of actual local insolation gain distribution curve is crucial for the proper solar gain estimates.

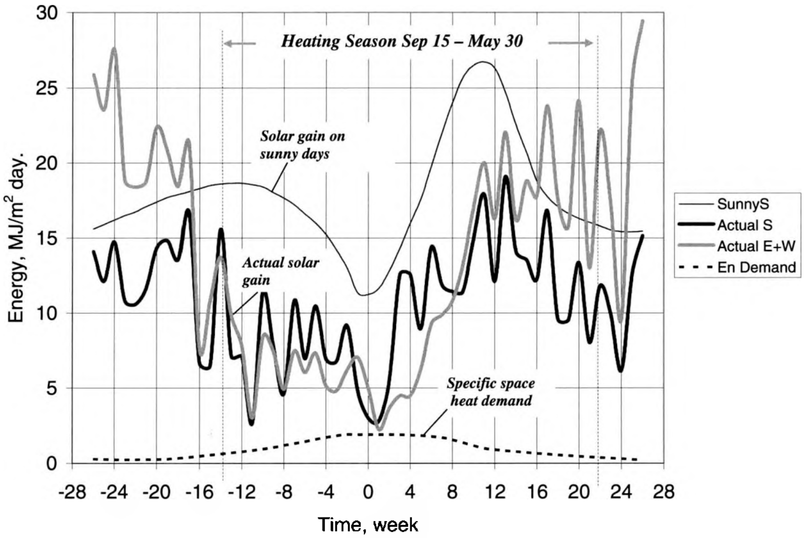

Fig. 1: Solar gain potential for south and west/east exposed walls in comparison with a specific energy demand by residential house located in Central Canada (latitude 54°N).

The analysis of data on insolation for the vertical, south exposed wall shows an existence of unusually high insolation level for sunny days, with culmination in March. This spring peak is related to a combination of the high albedo (reflection from snow cover) and incident angle of solar radiation. Considering a long heating season in Central Canada region (up to seven months), the additional energy gain, that can be obtained form the eastern and western walls, is critical and implementation of the three-wall solar system appears to makes a lot of sense.

Technology Description and Testing

The DHS solar technology relies on the application of the glazed, heat accumulating PCM layer that is installed on the external wall of the building. As a result, the solar energy is collected and stored directly in the building envelope. When exposed to sun, the DHS solar collector is charged by the sun and accumulates a significant amount of heat. During the night, the accumulated heat keeps the panel warm for a prolonged period of time. The elevated temperature in the buffer zone prevents heat loss through the walls, and in consequence, reduces the amount of energy required for the building heating. The DHS system can be considered as a semi-passive solar system, which is equipped with a motorized shading system. Two modes of the DHS system operation are predicted. In the winter mode, during the day, shutters are up allowing absorption of the maximum amount of solar energy in the DHS panel. During the night shutters are down to reduce heat loss. In the summer mode of operation, the system action is reversed and the shutters are down during the day to block heat access to walls and are up in night to allow the thermal energy to be discharged to the ambient atmosphere. The DHS thermal solar collector with direct heat storage (DHS) as shown in Fig. 2 consists of a thin insert with a PCM material and a transparent cover (glazing).

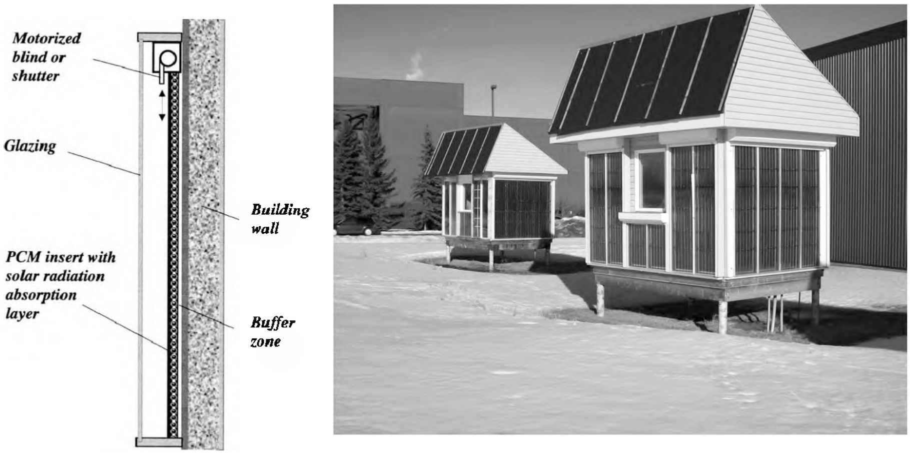

Fig. 2: DHS solar collector concept and shelters equipped with DHS panels.

To test the DHS solar technology, in total four models of houses (shelters) were constructed. Two shelters were equipped with the DHS solar system and two other were used as reference structures. The reference shelter (#1) represents a house constructed to the current standards in Alberta (wall RSI 3.5). The second model (#2) represents the new, more energy efficient technology (structural insulating panels (SIP) wall RSI 4). The third (3#) and fourth (#4) shelters are combination of the first two with the DHS solar system added as shown in Fig. 2. In the first series of tests, the solar shelters were tested over the winter period to determine the energy consumption for space heating. In the second, the system was switched to the summer mode of operation and tested during the summer.

Test Results for Heating Period

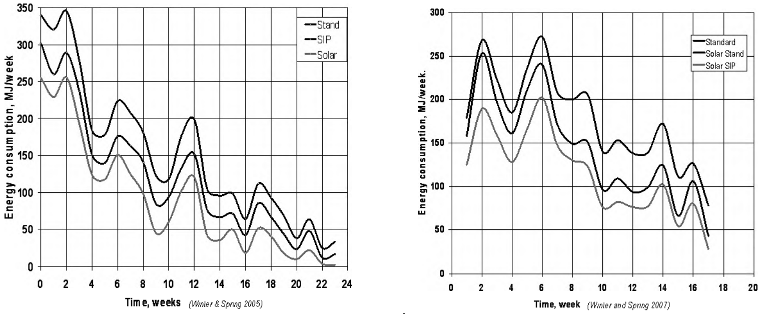

Fig. 3: Shelters energy consumption for space heating.

The results on energy consumption (on a weekly basis) by the tested shelters over a heating season are shown in Fig. 3. In comparison with the Standard shelter, which is considered to consume 100% energy, the SIP shelter consumed 76% of energy and the Solar shelter reduced the consumption down to about 55%.

Test Results for Cooling in Summer

In summer, the DHS system operation is reversed and the DHS system is utilized to protect walls from overheating and stabilize the temperature in the building. During the day, the southern walls were exposed to a solar radiation of up to 700 W/m^2. The south walls temperature for Standard and SIP shelters were about 43 °C and 41 °C accordingly. The south wall (buffer zone) temperature for the Solar shelter was much lower, with a maximum value of 27 °C. During the night, the walls temperature gradually decreased down to 10 °C following the outdoor temperature trend. As shown in Fig. 4, application of the PCM material in the summer significantly reduces the indoor temperature fluctuations and keeps the indoor temperature in a comfortable range.

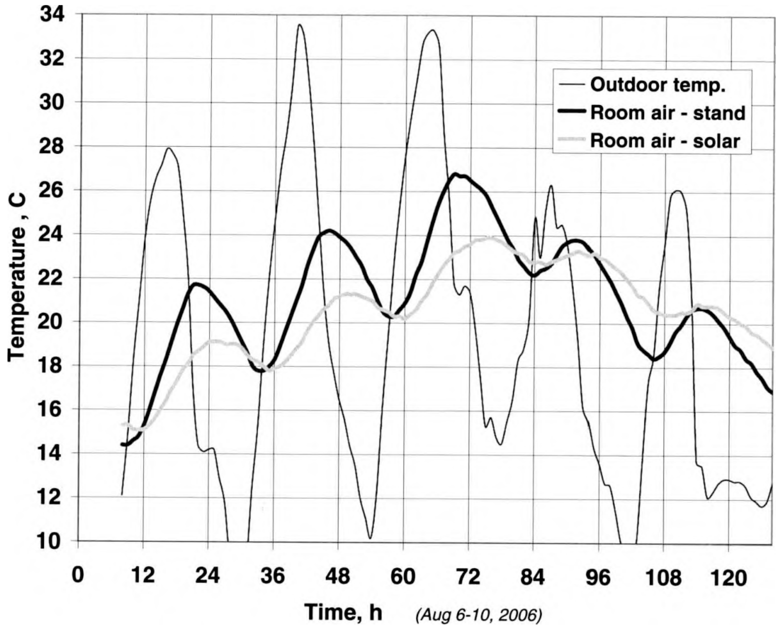

Fig. 4: Temperature profiles for indoor temperatures (August 6–10, 2006). (Range of outdoor temperature fluctuations from 9 °C to 33 °C)

Conclusions

The DHS panels installation on eastern and western vertical walls offers a significant additional source of energy and utilization of this potential for space heating in the cold climate regions is fully justified. The field tests demonstrated that the DHS solar thermal system can significantly reduce energy consumption for space heating as compared with traditional residential housing construction technology.

Testing of the DHS system over the summer season proved the system's ability to stabilize and moderate the indoor temperature during the summer.

Acknowledgements

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Monitoring results and operation experience from a solar thermal system for container washing in Parking Service Castellbisbal (Contank)

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INTRODUCTION

ParkingService Castellbisbal S. A., which belongs to the Spanish firm CONTANK, is a factory located in Castellbisbal (Barcelona), which was built between 2003 and 2004. Its main services are related to the the transport market: parking, external and internal container cleaning, and tank storage.

A 357 kWth solar thermal system was foreseen to be integrated since the first design phases of the industrial container washing process, since the beginning of 2003, in order to achieve an optimal integration in the factory.

The solar thermal system was optimized, designed and planned by AIGUASOL, promoted by GAE and installed by PATEL during the last months of 2004.

The solar thermal system had an estimated heat demand of 1990 MWh/year (using the data provided by the company), an expected useful heat gain of 429 MWh

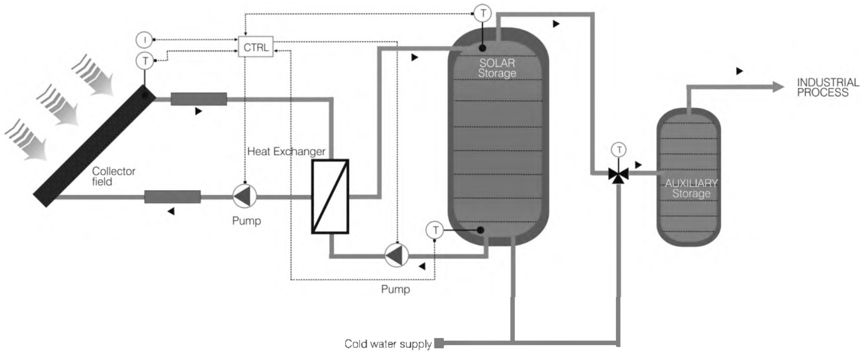
(841 kWh/m^2) and a solar fraction of 21.55%. The global solar radiation on horizontal surface was 1471 kWh/m^2.

The solar thermal system, which had a total investment cost of 268 546.02 €, was partly funded (43.1%) by public administrations from the Spanish and Catalan governments (IDAE and ICAEN respectively). The expected pay-back time calculated was 9 years.

Technical characteristics

The solar thermal system is composed by a pressurized primary loop filled with anti-freeze heat transfer fluid (30% glycol), a heat exchanger, and a secondary non-pressurized loop of decalcified and pre-processed water for industrial container washing.

The solar collector field, placed with an azimuth 24° east and 25° of slope, is composed by two fields at different levels with a total absorber surface of 510 m^2. Solar collectors are connected so that there is a low-flow, rate 17 kg/h.m^2. Collector rows were installed with foreseen distances of the initial architecture project design. A 45 m^3 atmospheric stainless steel solar water storage tank, supplies preheated water to the process.



A thermostatic valve was installed, which was not considered in the initial project, and ensures that the process water temperature is not higher than 55 °C.

In the case of the CONTANK system, the auxiliary energy is not delivered in the auxiliary tanks but through a tubular heat exchanger which provides energy from a steam boiler. Therefore, the energy is instantaneously given to the water for the cleaning process.

TRNSYS simulations (through TRANSOL [1] tool) were run for the optimization of the solar thermal system and heat production estimation.

Monitoring results

A detailed monitoring system was also installed and it is in full operation since July 2006. Data obtained from January to September 2006 (except from April to June) has given us the chance of checking the real system operation, its real performance, and real input data such as demand profiles or local global radiation in order to validate the used TRNSYS model.

Global incident radiation monitoring results

The real global incident radiation on the collector surface evaluated from July 2006 to September 2006 was 6.4% higher than the global radiation used in the simulations for the same period.

Consumption

The real consumption evaluated from January to March and from July to September 2006 is 55.7% lower than the estimated consumption used in the simulations for the same period.

There are mainly two factors involved in this mismatch between the real consumption and the estimated one:

- Nominal working conditions not achieved (80–100 m^3/day; 5.5 day/week)
- Percentage of cold water in the cleaning process is higher than expected.

The reduction of the consumption involves a reduction of the performance of the solar thermal system, as well as a decrease in the expected energy delivered to consumption.

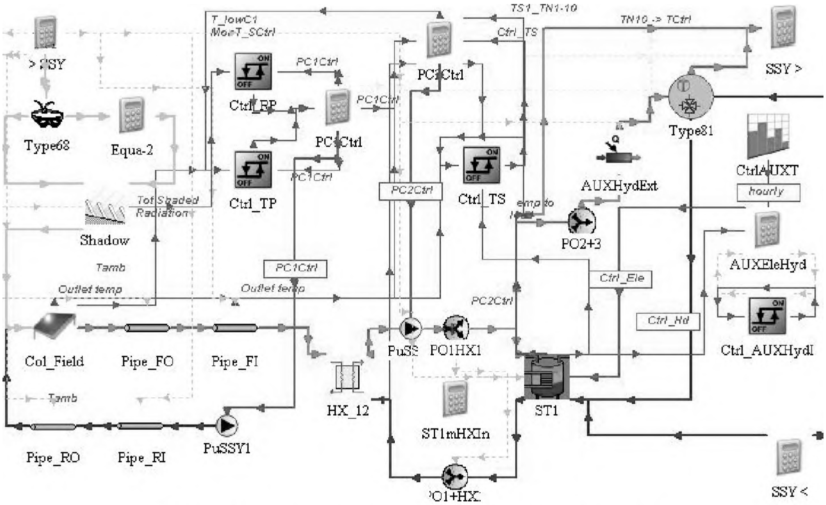
Simulation model validation

In order to validate the TRANSOL simulation model used for the forecast of the system operation and its performance, new simulations with the updated data obtained from the monitoring are necessary.

The monitoring data which will be useful for the new simulations are:

- Real consumption load profile.
- Cold water temperature monthly average values.
- Global radiation on tilted surface, which was not used due to the small period in which the data has been obtained (only three months).

Taking into account the new data obtained by the monitoring scheme new simulations were developed in order to check the TRNSYS model.



ENERGY DELIVERED TO THE SOLAR TANK

In the new simulations, the real amount of energy delivered to the solar tank evaluated from January to March and from July to September 2006 is 8.4% higher than the simulations for the same period. Considering that the real global incident radiation upon the collector surface evaluated during the same period was also 6.4% higher than the global radiation used in the simulations, the obtained results fit mostly to the real system operation and performance.

ENERGY DELIVERED TO THE AUXILIARY TANKS

The energy delivered to the auxiliary tanks, however, is 14.6% lower than the results we obtained in the updated simulations for the same period.

This reduction is thought to be mainly due to the night cooling application implemented and not considered in the design TRANSOL simulations.

OPERATION EXPERIENCE

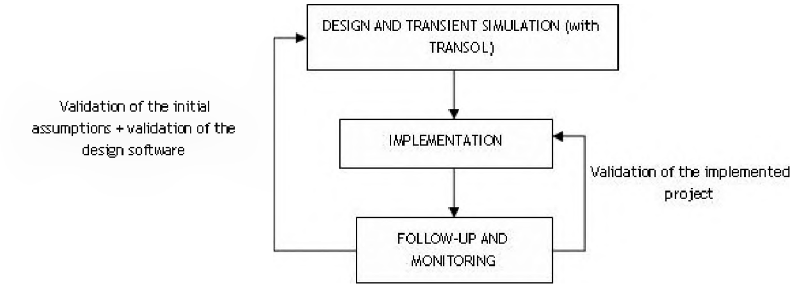
During this first year and a half the CONTANK solar thermal system has not been working at full operational conditions. A lower consumption has forced, during potential stagnation periods, to apply delaying stagnation measures, such as night cooling of the solar tank.

Incidences

No solar system is exempt of incidences during its first years of operation. This is the main reason for the continuous follow-up that AIGUASOL has done in the CONTANK factory. It has helped us anticipate and solve most of the incidences that such a complex system had.

Conclusion

AIGUASOL has followed a three step feedback methodology, which ensures the correct operation of the systems.



The TRANSOL model, simulated with the real actual working conditions, approaches nicely to the behaviour of our solar thermal system.

Monitoring results, hence, are the key to validate the design tools used, to review the initial demand assumptions and to check the real system operation and performance. Monitoring data also demonstrates a lower consumption than the initial estimation mainly due to a lower use of the cleaning plant, which obligates to implement night cooling measures in order to soften stagnation conditions.

Despite this, the solar thermal system has been working in the expected performance and almost 1/3 of the energy demand (during the months in which the data have been obtained) has been given by the solar system.

References

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Linear Concentrating Fresnel-Collector for Process Heat Applications

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Introduction

Linear Fresnel-Collectors use individually tracked reflector rows to concentrate direct solar radiation onto a stationary linear receiver. The optical concentration allows for high operation temperatures and the Fresnel approach promises low wind loads, high ground coverage and a relatively simple and low cost construction.

PSE GmbH developed a linear concentrating Fresnel collector to produce process heat of up to 200 °C and starting with a peak capacity of around 50 kWth. The collector is well suited to be mounted on flat roofs. In December 2005 a first prototype with 88 m² mirror area was installed in Freiburg, Germany. The collector was operated and evaluated through summer 2006.

A second prototype with 132 m² aperture area was installed in Bergamo, Italy to power a NH_3/H_2O absorption chiller. The complete solar cooling system is operated and monitored since August 2006.

Fig. 1: PSE linear Fresnel Process Heat Collector powering two NH_3/H_2O Absorption Chillers of Robur S.p.A. in Bergamo, Italy

Construction principle and design parameters

The objective of our development is a collector for the generation of process heat with up to 200 °C and for a minimum thermal peak capacity of about 50 kW. Individually tracked rows of glass mirrors concentrate the sunlight onto a vacuum tube receiver with secondary CPC made of aluminium. The general collector design consists of modules that can be combined for large collector fields. One module is 4 m long (this is the length of the vacuum receiver) and 7.5 m wide. 11 mirror rows with 0.5 m width are mounted with a distance of 0.2 m to each other. This results in an aperture width of 5.5 m and an aperture area of 22 m² per module. The collector is well suited to be mounted on flat roofs of e.g. industrial halls. Due to the low wind load it is possible to mount the collector without hurting the roof cladding.

Length	Modular in steps of 4 m
Width of the mirror field	7,5 m
Aperture width	5,5 m
Distance between mirrors	0,2 m
Height of the receiver	4 m above mirror field
Number of mirrors	11
Width of mirrors	0,5 m

Table 1: Dimensions of the collector

The optical efficiency and the Incident Angle Modifier (IAM) of the collector were derived from detailed ray-tracing simulations (1). Heat loss measurements of DLR that were published for the Vacuum Receiver SCHOTT PTR® 70 (2) were transferred to a quadratic heat loss coefficient with respect to the aperture area (see Table 2 and Fig. 2)

Optical efficiency η_0	0,58
Heat loss coefficient	4,3 10^{-4} W/m²K²

Table 2: Collector performance parameters

Performance measurements

Our first prototype was installed on the roof of the PSE workshop in December 2005. The collector was operated during summer 2006 for detailed performance measurements, which were evaluated in co-operation with the Fraunhofer Institute for Solar Energy Systems.

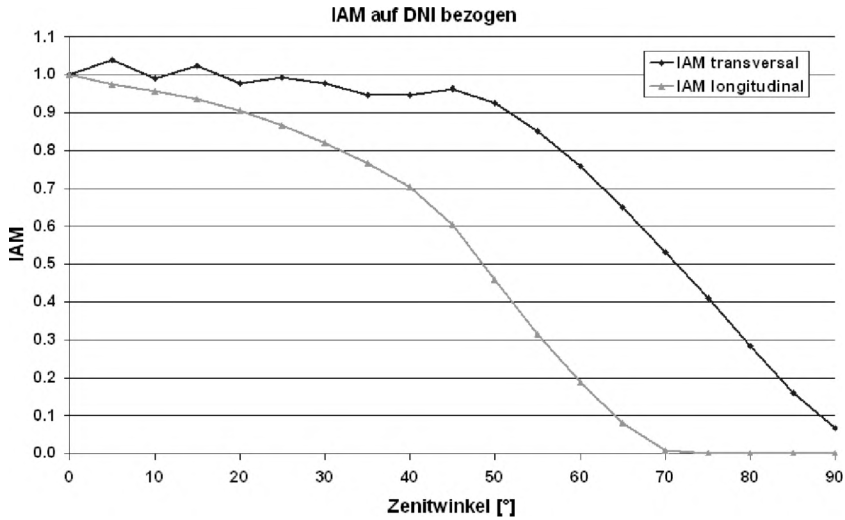

Fig. 2: Incident Angle Modifier of the first prototype

Fig. 3: PSE linear Fresnel Process Heat Collector on the roof of the PSE workshop

The efficiency of solar thermal collectors is only defined for normal irradiation. However, in Freiburg the sun is never perpendicular over a horizontal collector aperture. This is why we took into account the IAM of Figute 2 in order to derive an efficiency curve for normal irradiation out of our performance measurements.

Due to the "non laboratory" conditions of our setup we could only identify measurement points by weakening the boundary conditions that are required by EN12975 for stationary performance measurements of solar thermal collectors. Naturally this led to a big scatter of the measurement points. Fig. 4 gives the results of our efficiency measurements and the derived linear efficiency curve. The data basis is not sufficient to estimate a quadratic heat loss coefficient.

Even if the uncertainty of the measurements is very high we can conclude that the theoretically derived optical efficiency is confirmed. However the heat losses of the receiver are higher than expected. This might be due to a loss of vacuum in the tube and needs to be investigated in more detail with pure heat loss measurements.

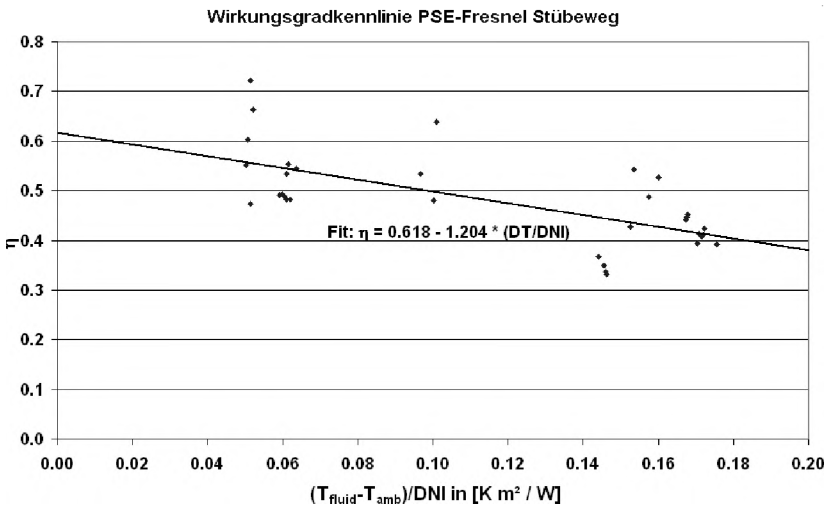

Fig. 4: Efficiency measurements of the first prototype collector

Summary and Outlook

Two prototypes of the PSE Linear Fresnel Process Heat Collector were built and are continuously operated and monitored. The first installation is used for detailed performance measurements. The second system is powering two absorption chillers and demonstrates the reliable operation and good matching of the chillers with the collector.

Both plants confirm our expectations in the performance of the collector and demonstrate an attractive technology for the solar generation of industrial process heat and its use for solar cooling. Further demonstration projects are planned for 2007. We plan to offer the collector on a fully commercial basis in 2008.

Acknowledgement
The development of the PSE linear Fresnel process heat collector was co-funded by the Deutsche Bundesstiftung Umwelt.

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Testing Unit for the Development of Process Heat Collectors up to 250 °C

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Introduction

In the development of flat-plate collectors and vacuum tube collectors for domestic hot water and for room heating applications it was sufficient to carry out collector efficiency measurements up to collector inlet temperatures of about 100 °C. But the situation is different for the development of collectors which will have their main operating temperature in the range of 100 to 250 °C. It is essential to carry out efficiency measurements directly at these high temperatures and not to rely on extrapolations from measured efficiency points at lower temperatures.

At Fraunhofer ISE, we have set up a new test rig, with which we can measure efficiency curves for temperatures up to 200 °C.

New testing facility for indoor and outdoor measurements

For our collector measurements at Fraunhofer ISE, we use both an outdoor test stand with a tracker and an indoor test rig with a solar simulator, which can operate independently of the weather. These test facilities are used both for certification measurements and for development work. We have developed the new testing unit for process heat collectors as an additional module, which can be used in both test facilities. This extends our experimental basis for developing process heat collectors: For concentrating collectors, parabolic trough collectors or CPC collectors, the outdoor test stand must be used because of the need for direct radiation, whereas non-concentrating collectors can also be investigated with the indoor test rig. This offers the advantages of saving time and costs due to independence from the weather, which is particularly important for developmental work, better reproducibility and greater flexibility for specific experimental investigations. Moreover, also for many developmental questions on concentrating collectors the indoor testing facility can be used, for example with regard to heat losses, checking the temperature durability of materials and collector components at high temperatures and constructive aspects.

Concept of the test facility

We decided to design the new testing facility in such a way that measurements are possible up to 200 °C and to use pressurized water as heat transfer fluid. This very basic decision already defined many essential specifications for the components of the new testing unit, because the saturated vapour temperature of water at 200 °C is 15.3 bar. All components of the testing loop must withstand these conditions at least. We designed the test stand for a maximum of 200 °C and 20 bar.

Of course, this also means that only collector constructions that withstand the high pressure during testing may be tested at the corresponding high temperatures. But in practice this is only a small disadvantage which has to be accepted due to the decision to use water as heat transfer fluid.

On the other hand, water offers many advantages compared to synthetic heat transfer oil which was also taken into consideration: The specific heat capacity c_p of oil may change due to the thermal stress and degradation over time. For exact measurements, the value of c_p must be checked continuously and re-calibrated. Oil has a higher capability of creep and it is more difficult to avoid leakage points. It is also more difficult to keep the testing facility clean, especially if the testing collectors have to be changed often. Oil is environmentally sensitive and requires safety measures such as protective troughs. And oil vapours are harmful to health. Finally, oil is expensive and water is cheap.

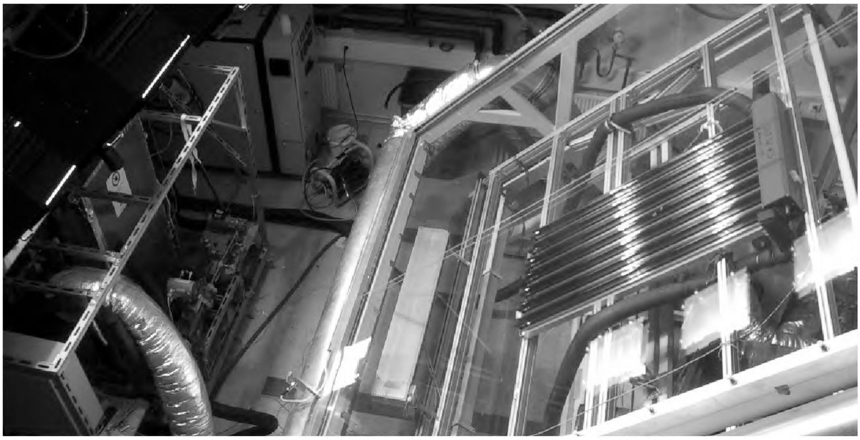

Fig. 1: Efficiency curve measurement for an evacuated tubular collector with a CPC reflector exposed to the solar simulator at Fraunhofer ISE. The new testing unit, with which we can make accurate measurements up to 200 °C, is at the bottom left of the photo.

The measuring range for the mass flow in the collector testing loop is 60 to 1000 kg/h. The accuracy of the temperature measurements is better than 0.02 K over the whole range up to 200 °C for the inlet and outlet temperature, due to our own calibration routine and collector testing experience.

Measurements

Fig. 2 shows examples of measured efficiency curves of three different collectors. All curves were measured in our solar simulator laboratory (indoor measurements) and with the new testing facility. The highest measurement points were taken at mean collector temperatures of about 185°–190 °C for all three collectors. The actually measured efficiency points are indicated in the diagram for the evacuated tubular collector 1. It is a collector without a CPC reflector and with relatively narrow gaps between the single evacuated tubes. These measurements were taken at an irradiation of 931.9 W/m². Therefore also the two other curves are given for this irradiation so that all three curves can be plotted in one diagram. In all measurements the ambient temperature was in the range of about 30 °C.

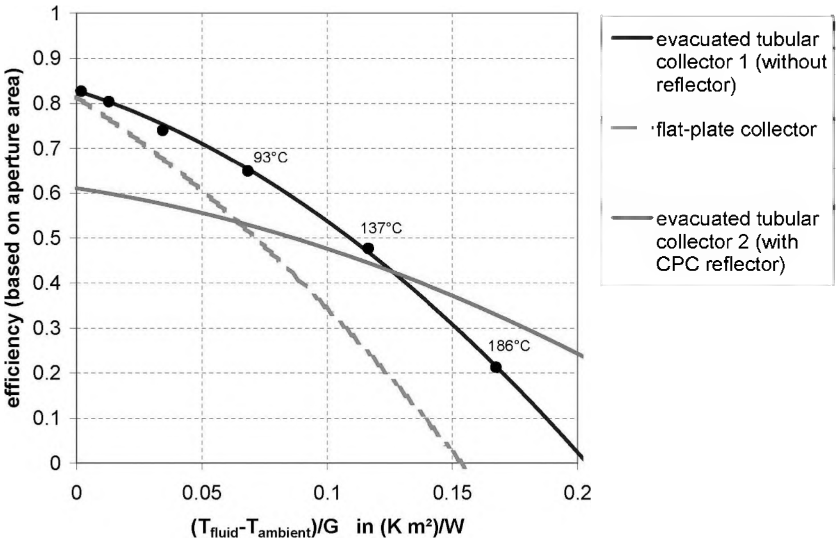

Fig. 2: Measured efficiency curves of three different collectors (indoor measurements) with solar simulator, highest mean collector temperatures about 185°–190 °C for all three collectors. The dots show the actually measured efficiency points for collector 1 and the mean collector temperature in the measurement.

The second evacuated tubular collector uses a CPC reflector. The heat losses based on the aperture area are therefore smaller and the efficiency curve is higher than for collector number 1 at higher operating temperatures. The efficiency curves show that both evacuated tubular collectors are suitable for system applications in which the collector operating temperature is in the range above 100 °C and may be up to 150 °C. The flat-plate collector has a highly selective absorber coating and is glazed with a single, anti-reflectively coated glass.

Conclusion on testing of collectors up to 200 °C

Why are collector testing facilities needed to carry out exact measurements up to 200 °C? There are two aspects: The first is development of new collectors for higher operating temperatures /1/. Many new applications, such as solar cooling and climatisation, solar process heat /2/ and sea water desalination /3/ will become possible and will spread on the markets world-wide. The experience in collector testing shows that it is not possible to extrapolate efficiency curves by more than about 20 to 30 K above the highest collector testing temperatures. It is definitively necessary to measure the collector efficiencies directly at the operating temperatures needed in the applications. Therefore, especially for the work to develop new collectors and to improve existing collectors for higher temperatures, it is necessary to carry out exact measurements in order to ensure real improvements and to assess them in an adequate way. Of course, the efficiency curve is not the only technical parameter needed. Additional technical properties such as the IAM (incidence angle modifier) and the thermal collector capacity do have an influence on the thermal performance. Also these technical parameters are needed. As well as a high service life time, which means that suitable materials and components are chosen and that the collector design fulfills all requirements in the real application. And definitively costs matter. This leads to the second aspect of the questions above: Exact measurements and the full information is needed for a complete *technical and economical assessment* of different collectors. The aim is to determine and to select the most suitable collector for an application. Especially in this temperature range of 80 to 250 °C very different collector designs are possible and under development right now: flat plate collectors with single and double glazing, CPC collectors with low concentration and collectors with high concentration of direct radiation (parabolic trough, Fresnel). The collector brochure of the IEA-Task 33 "Solar heat for industrial processes" gives an overview /2/. More work, based on more exact information will have to be carried out in the future, in order to achieve an adequate technical and economical comparison of these very different collectors.

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Thermochemical storage – first simulations and experiments

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INTRODUCTION

Traditional heat storage techniques have a number of disadvantages for long-term heat storage, such as substantial heat loss and relatively low energy density (large volume). As an alternative, it is possible to store energy by means of chemical processes, making use of the reversible chemical reaction:

$$A + B \Leftrightarrow C + heat$$

Interesting reactants are low cost, non-toxic, non-corrosive, have sufficient energy storage density and have reaction temperatures in the proper range. These requirements are fulfilled by a number of salt hydrates. In a previous study at ECN (Visscher et al., 2004), magnesium sulphate has been identified as a particularly suitable storage material, by means of the reaction

$$MgSO_{4(s)} + 7H_2O_{(g)} \Leftrightarrow MgSO_4 \bullet 7H_2O_{(s)} + 411 kJ/mol\_MgSO_4$$

This material could be interesting for seasonal storage. During winter, when heat is needed for e.g. residential heating, the magnesium sulphate is hydrated, producing heat. During summer, the hydrate is dehydrated by heat from a solar collector, which can be regarded as recharging the material. Once the chemical reaction has taken place, the solar heat can be stored for a long time without losses.

This paper summarizes the experimental and numerical results found in the MSc graduation work of Ilse van de Voort, second author to this paper. The work on thermo chemical heat storage is part of the long-term work at ECN on compact storage technologies.

EXPERIMENTAL WORK

Simulations and experimental work have been carried out in order to characterize the dehydration reaction of $MgSO_4 \times 7H_2O$. The experimental work has focused on thermogravimetric (TG) measurements (measurement of mass as a function of temperature, showing the reduction in mass if the sample is dehydrated). In Fig. 1, the mass is presented as a function of temperature. The figure clearly shows a decrease in mass of roughly 48%, which almost corresponds to full dehydration of the $MgSO_4 \times 7H_2O$ (corresponding to a 51% decrease in mass). The difference can be explained by the fact that at the start of the measurements, the sample may already have lost some water, so that actually a sample consisting of a mixture of $MgSO_4 \times 7H_2O$ and $MgSO_4 \times 6H_2O$ was dehydrated during the measurement. In addition, Fig. 1 also shows the differential mass (mass change), which shows more clearly at what temperature the largest loss of mass occurs.

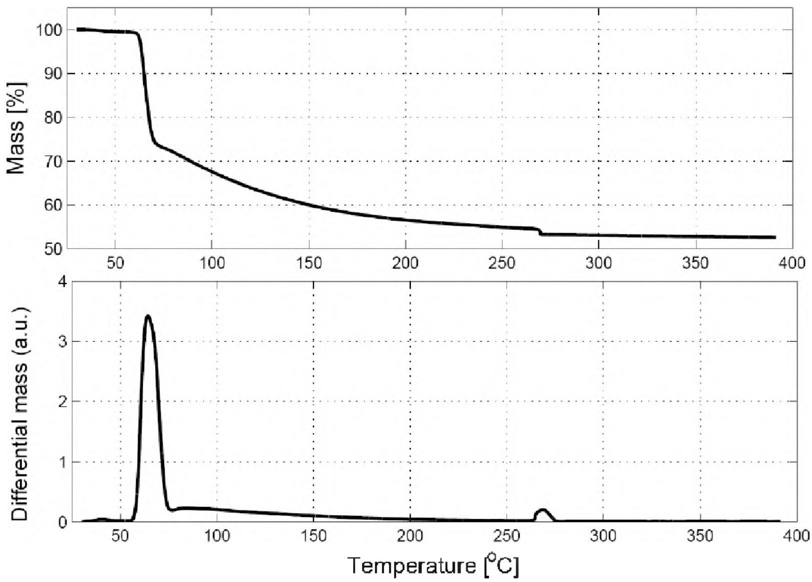


Fig. 1: TG measurement results on $MgSO_4 \times 7H_2O$

Now in the measurements, a number of parameters could be varied. The results illustrate the significant effects of heating rate, air moisture, particle size and layer thickness on the dehydration, as can be seen in Fig. 2 and Fig. 3.

Fig. 2 shows that the reaction shifts to significantly higher temperatures at large heating rates and/or water vapor pressures (the heating rate in Fig. 2b is 5 K/min, corresponding to a temperature range of 25–200 °C). In addition, thicker layers and larger particles also shift the reaction temperature to higher values, indicating that heat- or vapor transport is limiting the reaction rate.

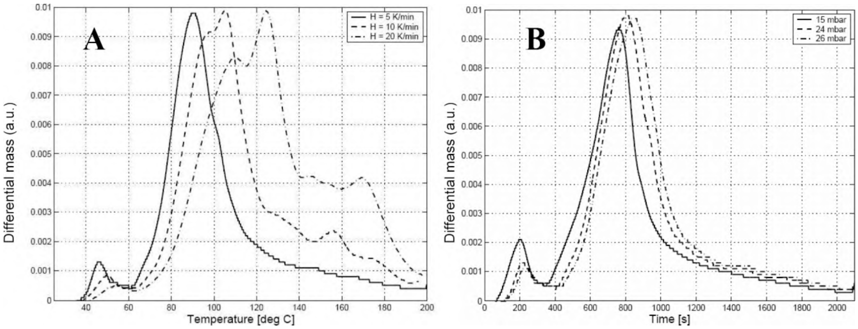


Fig. 2: Effect of (a) heating rate and (b) air moisture on TG-measurements

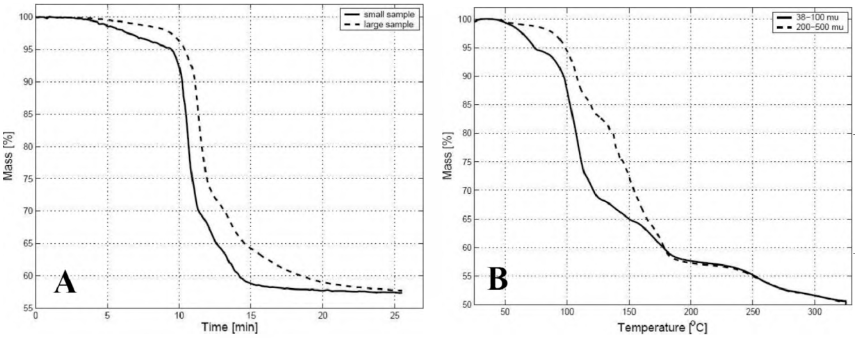


Fig. 3: Effect of (a) layer thickness and (b) particle size on TG measurement results.

Up till now, only the dehydration reaction has been discussed. However, when using the material for heating purposes, it is the hydration reaction that determines the power that can be delivered. Some preliminary measurements on the hydration have been carried out. In Fig. 4a, from 0–175 minutes the sample is heated at a constant rate of 1 K/min from 25 to 200 °C, from 175–350 minutes the sample is cooled at the same rate and finally, during 350–550 minutes, the sample is kept at a constant temperature of 25 °C. The moisture content of the airflow at ambient temperature and ambient pressure is set to 80%. The hydration reaction is observed to take place at relatively low temperatures and to be rather slow compared to the dehydration reaction, as indicated in Fig. 4a. Fig. 4b shows the result of thermal cycling at 30 K/min between 45 °C and 150 °C. The figure shows that under these conditions the cyclability of the material seems problematic, since the water uptake decreased significantly over a few cycles. Possibly, this may be related to partial melt of the material during the fast heating in the cycling test. Further characterization work on hydration and cycling is ongoing.

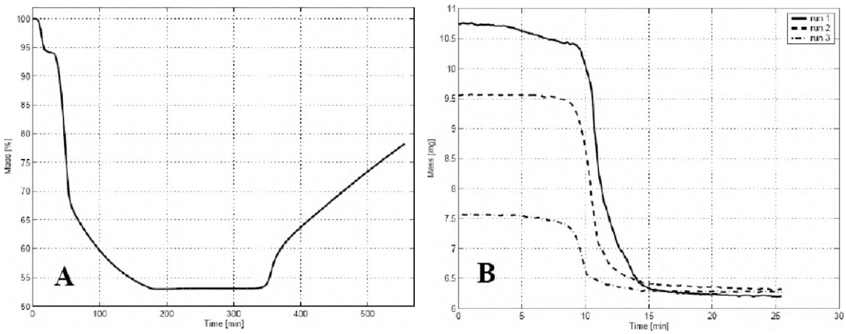
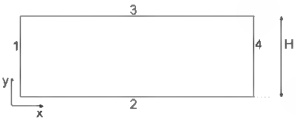


Fig. 4: (a) Dehydration-hydration TG measurement (b) Thermal Cycling TG experiment.

Simulation work

A 2D finite element model is built in COMSOL Multiphysics. A porous layer of hydrated magnesium sulfate is considered as a homogeneous continuum and the heat and mass transport through this layer are calculated.



	B1	B2	B3	B4
Heat	$\vec{q}\cdot\vec{n}=0$	$T_{prescribed}$	$-\lambda\nabla T\cdot\vec{n}=0$ $\vec{q}\cdot\vec{n}=\rho c_p T\vec{v}\cdot\vec{n}$	$\vec{q}\cdot\vec{n}=0$
Mass	$N_i\cdot\vec{n}=0$	$N_i\cdot\vec{n}=0$	$N_i\cdot\vec{n}=c_i\vec{v}\cdot\vec{n}$	$N_i\cdot\vec{n}=0$

Fig. 5: Model boundary conditions

The chemical reaction rate is described by the Arrhenius relation, the constants of which were determined experimentally. From an analysis of the effect of heating rate on mass change, an activation energy of 55 kJ/mol was found, together with a frequency factor of 1.67×10^5 Hz. Other model input parameters, such as material constants, are obtained either from literature or from experiments. The model has been validated by a comparison between experimental and numerical results for some base case problems, as shown in Fig. 6.

The simulation results show fairly good correspondence to the measurements. However, it appears than the single value for the Arrhenius activation energy used in the model does not fully capture the dynamics of the process. This is also found in the literature. Ruiz-Agudo (2007) distinguishes in the dehydration the following steps:

(1) $MgSO_4 \times 7H_2O$, (2) $MgSO_4 \times 6H_2O$, (3) amorphous hydrate, (4) anhydrous $MgSO_4$. He indicates that the activation energy increases continuously (and not stepwise) at low moisture fractions. The model shows the distribution of the different phases in a layer of material as a function of temperature (Fig. 7).

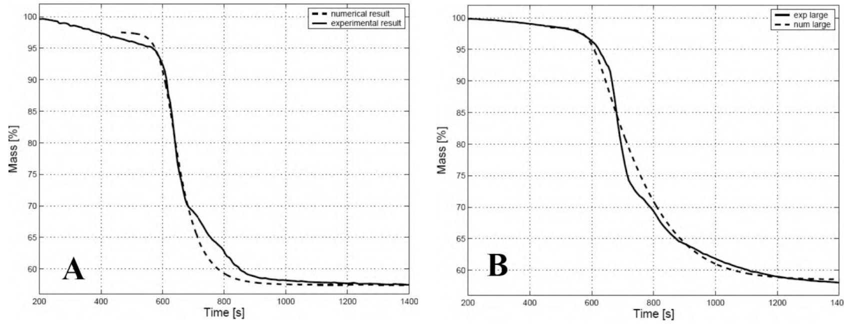


Fig. 6: Comparison of experimental and modeling results (a) 11 mg sample (b) 38 mg sample

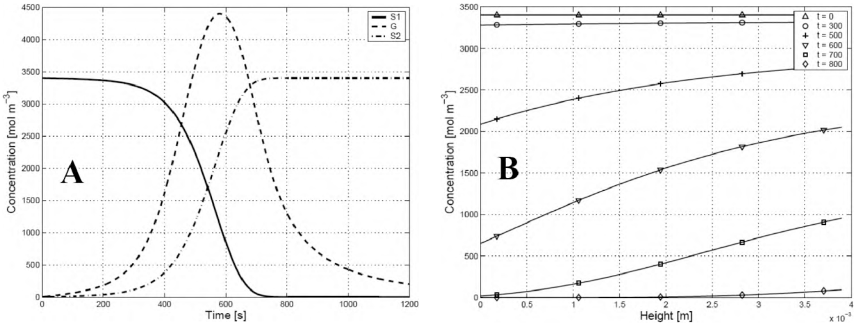


Fig. 7: (a) Concentration variation over a reaction step (solid1 solid2, the gas is continuously removed at the upper domain boundary), (b) concentration of solid1 over the domain height as a function of time. T ranges from 20 to 200 °C, heating rate 10 K/min.

CONCLUSIONS

TG measurements on $MgSO_4 \times 7H_2O$ show effective dehydration. The effects of heating rate, particle size and layer thickness are substantial, indicating that heat- or vapor transport are limiting the reaction rate. Hydration measurements indicate that the hydration characteristics and cycling may be problematic and should be examined more closely, which will be part of the next phase of the project. Also the numerical scheme showed good results, but may be improved further by allowing for the activation energy as a function of the moisture content.

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Intelligent and Advanced Solar Cooling System based on the Novel Technological Development "SOLITEM Parabolic Trough Collector PTC 1800"

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Introduction

The sun is the ultimate energy source and its energy surpasses the world's primary energy demand more than a ten thousand times. In this manner, the main goal of SOLITEM is to utilize the use of this enormous energy potential directly into the air conditioning, as it will take the largest share in the future energy mix.

Despite the rising prices for fossil energy sources, solar energy will always be abundant and is decentralised available through the world.

In the Mediterranean Countries as well as in Arabic countries and in other solar rich countries, nearly all public buildings like hotels and hospitals require air conditioning during the summer time. For this purpose, there is a great demand for electricity since most of today's air conditioning systems are based on electricity powered compression cooling systems. Due to the fact that the solar radiation is simultaneous with the cooling demand, it is expected that absorption cooling systems can be operated more economically compared to the existing conventional cooling systems.

The SOLITEM Group as an innovative company develops and sets up absorption cooling systems operated with its own developed and patented parabolic trough collectors (SOLITEM PTC®), which do not only reduce the high electricity demand and costs for cooling, but also supply a CO_2 emission-free energy for the buildings.

The purpose of SOLITEM's development is an integrated energy supply system based on parabolic trough collectors which are combined with a double effect absorption chiller connected to an existing cooling, steam and hot-water system for summer application and a warm water system for winter application e.g. swimming pool heating, space heating etc.

Up to now SOLITEM has installed 4 Solitem solar cooling systems. At the "Iberotel Sarigerme Park" of the TUI group in Dalaman/Turkey, the first SOLITEM solar cooling system was installed and has been operated successfully since winter 2003/2004. In the project development phase, the components had to be optimised in terms of size to get the optimal design by means of energy saving and investment.

Since then, other solar cooling systems have been installed in Morocco, Jordan, Germany (in installing) and Turkey, and at present some other projects are performed in different countries in order to supply air conditioning and steam for summer applications, as well as warm water for winter applications in hotels, hospitals and industrial facilities.

The Parabolic Trough Collectors of Solitem (PTC)

In order to perform an efficient utilisation of solar energy by Parabolic Trough Collectors for cooling, heating and process steam generation, SOLITEM developed two different sized Parabolic Trough Collectors (PTC): The SOLITEM PTC 1800 for large applications and the small sized PTC 1100 for residential buildings. Both collectors have a supply temperature of 200 °C to 250 °C and are capable for roof mounting.

Fig. 1: SOLITEM PTC 1800 Parabolic Trough Collectors in Gebze/Turkey

On four locations SOLITEM Parabolic Trough Collector PTC 1800 systems have been installed and taken into operation. Three systems deliver heat for cooling with double effect absorption chillers as well as steam for laundry of the hotel and one system offers steam for industrial application.

Utilisation of high temperature heat for cooling

State-of-the-art of solar chilling:

Current solutions for solar chilling mainly use absorption chillers. The quality of energy transformation from heat to chilling energy is given by the coefficient of performance, COP = Chilling capacity/heating capacity. Mostly single effect absorption chillers are available with a limited operating temperature of the heat (< 100 °C) along with low COP values (annulaized) (< 0,6). Double effect absorption chillers offer higher COPs by converting the solar heat more efficiently into chilling energy. Therefore, high temperature heat should be used in double effect absorption chillers which requires a temperature of approximately 140 °C.

The elevated temperatures lead to higher thermal losses in the collector – the conversion efficiency overcompensates this effect by far though (Krüger et al., 2002). As it is seen in Table 1, double effect absorption chillers are mostly steam powered.

	Single Effect	*Double Effect*
Heating temperature	≤ 110 °C	≥ 140 °C
Fluid	water	steam, p ≥ 4 bar
COP (approx. annual value)	0,4 ... 0,7	1,2 ... 1,5

Table 1: Properties of single effect and double effect absorption chillers

Single Effect; Double Effect

Consequently, a double effect steam powered absorption chiller was preferred for the system. The chilling capacity of the machine enables operation in partial load (between ½ and ¾ load) for a wide range of operating time. For this range, Fig. 2 shows COP values starting from 1,4 to 1,5. The assumed average value is 1,4.

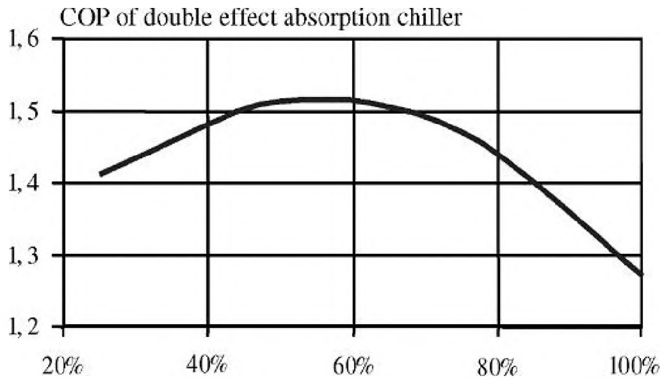

Fig. 2: COP values of double effect absorption chiller at partial loads

The system has an additional transforming device: Heat comes from the primary hot water by using high temperature solar thermal collectors is transformed into 4-bar saturated steam (143,6 °C) by means of a steam generator. A steam system provides diverse oppurtinities for solar heat utilisation, e.g. process steam demand in many industrial sectors such as textile industry.

System Operation Modes

The SOLITEM system has at least two operating modes. These modes enable to replace high expenses of fuel and electricity by available solar energy. The operating modes depend on boundary conditions like price level of electricity and fuel. Moreover, the modes depend on daytime and behaviour of the energy consumers (chilled water, steam and heat) as well.

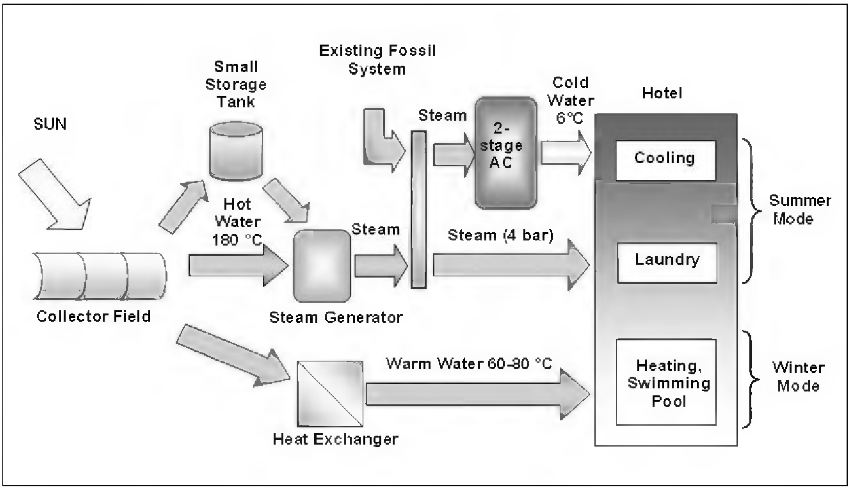

Fig. 3: Schema of the Solar Cooling System based on the Novel Technological Development "SOLITEM Parabolic Trough Collector PTC 1800"

The most important point is SOLITEM's system has bivalent operation. The SOLITEM system is operated with a combination of conventional systems, which clearly contributes the economy. Furthermore it is differentiated between low and high tariff rates depend on daytime. As an example, at the location of the system in Turkey there are three different tariff zones. In low rate times, where the electricity is quite favourable, the system generates less cooling energy wherewith more process steam is provided. In high rate times, where electricity is quite expensive, the system provides primarily cooling energy to save as much as possible expensive electricity. This operating method is the main characteristic of the summer mode (cooling and process steam).

Another important advantage is the opportunity to operate the system also in winter mode (heating). In winter mode warm water and space heating for building and swimming pool is generated. In this mode the collector field is operated with a lower working temperature of 60 °C–80 °C. In winter mode heat will be transferred in an additional heat exchanger and pipes with a second pipe system (warm water system). The outcome of this intelligent combination makes the system more economic and competitive in the market.

The absorption chiller operates at peak loads exclusively with solar generated steam. Based on the double-effect principle of the absorption chiller, 140 kW cooling capacity at full load with a Coefficient of Performance (COP) of 1.3 is achieved. The cooling water inlet temperature averages 37 °C–29 °C. The transmitting process of solar heat into cooling water can be optimised fundamentally if it takes place in part load. In the area of part load COP scores up to 1.5.

Compared with single effect cooling system, double effect cooling system's COP is almost three times higher. So that, the required collector surfaces decreases about 60% which makes the high temperature solar thermal collector system more economic and gives a technically high dynamic ability.

The modularity of these systems offers to increase the capacity by adding more high temperature solar thermal collectors more solar energy is utilised.

Conclusion

Parabolic trough collectors are able to deliver high temperature heat, which is a basic requirement for the efficient utilisation of great amounts of solar energy. These systems offer a wide range of opportunities to reduce costs of the energy supply. Combined with double effect steam powered absorption chillers, parabolic trough collectors make high efficient solar chilling possible. Worldwide SOLITEM is able to deliver, install and take into operation of the first economical and applicable high temperature solar cooling system.

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Techno-Economic Evaluation of Solar-Assisted Air-Conditioning Systems in Europe

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INTRODUCTION

In most European areas cooling and heating are both needed. Therefore, the capacity of each solar-assisted air-conditioning system to fulfil both these requirements is a key element for its techno-economic evaluation.

With respect to heating, a significant gap affects the different thermally driven cooling cycles. Actually, in the range of temperature required for the air-conditioning of the buildings, absorption chillers using H_2O/LiBr as working pair, both single and double-effect, can work only as cooling machines. As a result, a solar-assisted air-conditioning system combining this type of cooling cycle with collectors can not be exploited to cover the heating load too during the cold season. For this purpose it is only possible to directly use the heat produced by the solar collectors. On the other hand, cooling machines using NH_3/H_2O as working pair, can be also operated as heat pumps, with a heating COP around 1.6.

In the present study, both H_2O/LiBr absorption chiller and NH_3/H_2O heat pump, driven by any suitable low to medium temperature solar collector, are evaluated. The assessment is made on the basis of the overall primary energy saving, with respect to the reference conventional system, assumed as an electrically driven vapour compression heat pump with typical heating/cooling COP. The calculations are based upon the $\bar{\phi}$, *f-Chart* method, which has been implemented in a software tool, specifically developed by the authors for this type of analysis.

The inclusion in the investigation of both heating and cooling allows to select the best performing solar-assisted air conditioning system for each area, according to its global requirements. Furthermore, a wide range of locations, representative of different European weather conditions, being considered, this approach demonstrates that the feasibility of the application of solar thermal collectors for cooling needs is not limited to hot climate areas only.

This paper has been produced within the scope of the EU NEGST (NEw Generation of Solar Thermal systems) project [1], which overall objective is the introduction to the market of more cost-effective solar thermal systems. Actually, the utilization field of solar thermal collectors is traditionally limited to hot water preparation and space heating. The success of additional applications, such like the air-conditioning of the buildings, is certainly a crucial issue in order to support both a further diffusion of low temperature collectors and the promotion of innovative products, as medium temperature collectors designed for this specific use.

Description of the methodology

The approach adopted to perform the comparative analysis between the different solar heating and cooling systems can be synthesised in the following main steps:

a) Estimation of heating and cooling loads for a typical residential building located in sites representative of different European climatic conditions
b) Calculation of the related primary energy consumption attained by an electrically driven vapour compression heat pump, assumed as reference conventional heating and cooling system for the analysis
c) Definition of a reasonable fraction of the needed primary energy to be replaced by the solar energy
d) Evaluation of the collectors area required to achieve the fixed primary energy saving by means of a software tool
e) Comparison of obtained results

$\bar{\phi}$,*f-Chart* method [2], applied to a general solar heating system, has been used to perform the thermal analysis of each solar assisted air-conditioning system under investigation.

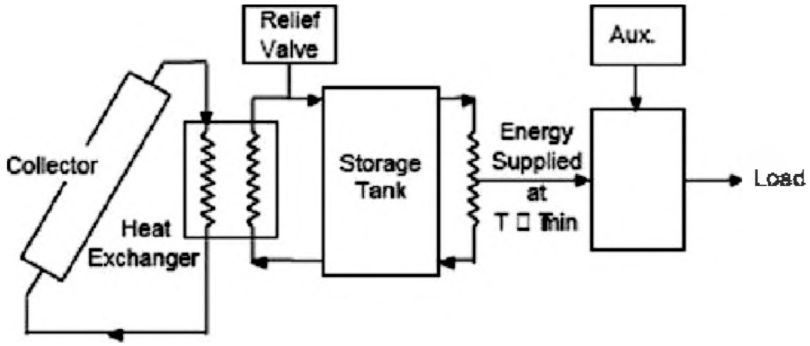

Fig. 1: Schematic of a general closed-loop solar heating system [2]

Fig. 1 shows the schematic of this type of solar heating system, which can be used in principle for a wide range of thermal applications including space heating and air conditioning.

For this kind of solar heating systems, the thermal energy is delivered when the temperature is above a specified minimum useful temperature (T_{min}). The value of T_{min} depends on the type of application: for residential space heating, T_{min} is the indoor temperature of the building; for thermally driven air-conditioning applications, it depends on the particular installation. An auxiliary heater provides to supply thermal energy when the solar input is insufficient to meet the load.

Reference locations

The comparative analysis has been carried out considering four reference locations, representative of different European climatic conditions:

- Palermo (Italy), representative of hot humid climate
- Lisbon (Portugal), representative of temperate climate
- Athens (Greece), representative of hot dry climate
- Rome (Italy), representative of warm climate

Heating and Cooling Needs

Table 1 shows the thermal loads for heating and cooling, evaluated on monthly-basis for a typical residential building located in the different European sites under investigation. The detailed description of the characteristics of the building envelope and the calculation hypotheses are reported in [3]. The values are in kWh per m² of conditioned floor area; the simulations have been conducted considering internal set point temperatures of 20 °C and 26°C for winter and summer season, respectively.

Month	PALERMO		LISBON		ATHENS		ROME	
	Heating [kWh/m²]	Cooling [kWh/m²]	Heating [kWh/m²]	Cooling [kWh/m²]	Heating [kWh/m²]	Cooling [kWh/m²]	Heating [kWh/m²]	Cooling [kWh/m²]
JAN	12.26	0.00	12.40	0.00	17.04	0.00	25.13	0.00
FEB	8.64	0.00	9.47	0.00	15.82	0.00	18.81	0.00
MAR	6.49	0.00	8.10	0.00	16.28	0.00	10.92	0.00
APR	1.91	0.00	6.89	0.00	8.45	0.00	5.27	0.00
MAY	0.00	0.44	0.00	2.54	0.00	3.01	0.62	0.00
JUN	0.00	4.20	0.00	6.95	0.00	9.61	0.00	5.00
JUL	0.00	12.73	0.00	11.81	0.00	17.25	0.00	13.85
AUG	0.00	14.77	0.00	13.17	0.00	18.44	0.00	14.71
SEP	0.00	6.70	0.00	11.77	0.00	13.86	0.00	4.38
OCT	0.00	0.81	0.00	5.52	0.00	5.01	1.78	0.00
NOV	3.75	0.00	7.79	0.00	6.72	0.00	14.61	0.00
DEC	9.62	0.00	12.27	0.00	14.19	0.00	24.68	0.00
Total	**42.65**	**39.64**	**56.92**	**51.76**	**78.50**	**67.17**	**101.81**	**37.95**

Table 1: Thermal loads for residential buildings.

Solar heating and cooling systems

An assessment of the different solar-assisted air-conditioning systems requires the preliminary identification of a reference conventional chiller, regarding which the primary energy saved by means of the exploitation of the solar energy is evaluated.

In the present analysis an electrically driven vapour compression heat pump, characterized by average COP values of 2.5 and 3.0 for cooling and heating respectively, is considered. Moreover, in order to assess the primary energy consumptions, a standard value of 0.4 for the conversion efficiency from the primary energy to the electricity from the grid is assumed.

With reference to solar-assisted air-conditioning systems, the following technologies are taken into account:

- Single-effect water/LiBr absorption chillers driven by flat plate (FPC) or evacuated tubular collectors (ETC)
- Double-effect water/LiBr absorption chiller driven by parabolic trough collectors
- Ammonia/water absorption chiller driven by parabolic trough collector (PTC).

Type of cycle	Cooling		Heating		Type of Collector	Efficiency curve parameters
	COP	Driving temperature	COP	Heat supply temperature		
SE - H2O/LiBr	0.7	85°C	-	45°C	FPC	η_0 = 0.78 U_c = 4.3 W/m²K
SE - H2O/LiBr	0.7	85°C	-	45°C	ETC	η_0 = 0.75 U_c = 1.8 W/m²K
DE - H2O/LiBr	1.1	150°C	-	45°C	PTC	η_0 = 0.74 U_c = 0.56 W/m²K
NH3/H2O	0.8	180°C	1.6	180°C	PTC	η_0 = 0.74 U_c = 0.56 W/m²K

Table 2: Design parameters adopted for the present analysis.

The main design parameters of each type of cycle are shown in Table 2. Since the analysis is performed on annual basis, for cooling cycles working only as chiller, the heat supplied by the solar collectors is directly used to meet the load during the winter season. This is accomplished by means of a common low temperature heat distribution systems for space heating, assuming a value of 45°C for the supply temperature.

Software tool

The calculations are made by means of an apposite software tool, implemented by the authors, which main characteristics are summarized below:

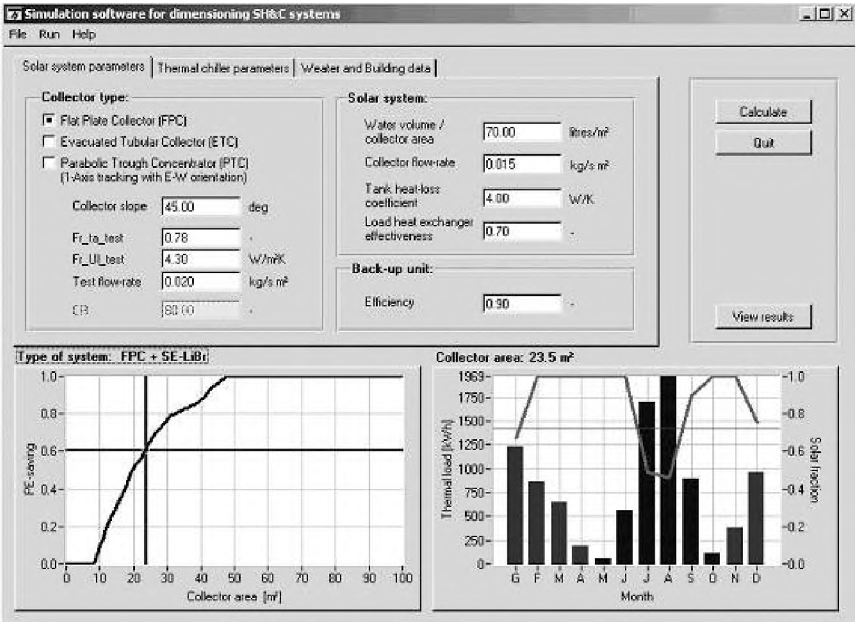

Fig. 2: Graphical user interface of the solar cooling design tool

- Annual solar fraction for heating and cooling is calculated starting from monthly-based average meteorological data and building loads (to be provided as input data).
- Solar fractions for heating and cooling are calculated on monthly basis.
- Solar system is mainly characterized by: the efficiency curve parameters of solar collector; the performance of back-up unit, the main features of the solar tank and heat-exchanger. A wide range of solar collector, ranging from flat-plate collectors, evacuated tubular collectors and concentrating collectors, can be taken into account.
- Thermal air-conditioning system is characterized by its cooling COP (and heating if reversible) and its driving temperature (both assumed constant during the working period). Single and double-effect H_2O/LiBr and NH_3/H_2O chillers can be analysed.
- The result is a curve that reports the variation of the primary energy saved, with respect to the reference conventional system, as a function of the collector area.

Results

In Table 3 the values of the required collectors area per m² of floor area to be conditioned, together with the corresponding annual solar fractions, are reported for each considered solar-assisted system. The results are calculated with reference to a primary energy saving of 70%.

Solar cooling system	PALERMO		LISBON		ATHENS		ROME	
	A_c/A_{floor} [m²/m²]	f_{sol} [-]	A_c/A_{floor} [m²/m²]	f_{sol} [-]	A_c/A_{floor} [m²/m²]	f_{sol} [-]	A_c/A_{floor} [m²/m²]	f_{sol} [-]
FPC + SE-H_2O/LiBr	0.24	0.76	0.24	0.76	0.37	0.76	0.41	0.76
ETC + SE-H_2O/LiBr	0.13	0.76	0.13	0.76	0.19	0.76	0.25	0.76
PTC + DE-H_2O/LiBr	0.11	0.71	0.10	0.71	0.17	0.71	0.26	0.73
PTC + NH_3/H_2O	0.10	0.70	0.10	0.70	0.16	0.70	0.14	0.67

Table 3: Required collector area (A_c) per square meter of conditioned floor area (A_{floor}) and respective annual solar fraction (f_{sol}).

Economic analysis

Given that cooling systems and solar collectors are both affected by a significant uncertainty, in this preliminary economic analysis a simple comparative approach is adopted. Therefore the economic assessment of each solar-assisted air-conditioning system is offered by the solar system investment cost and, as a result, by the total collectors area, if the same type of collector is used.

On the other hand, the comparison between systems using different types of collectors is based on the value of the ratio between the collectors cost per m², so that to have an equal solar system investment. Considering the current average costs affecting the various types of collectors, this value can offer a significant indication on the best performing system from the economic point of view.

Solar cooling system	Collector costs ratio per m² [€/€]			
	PALERMO	LISBON	ATHENS	ROME
FPC + SE-H_2O/LiBr	1	1	1	1
ETC + SE-H_2O/LiBr	1.85	1.84	1.91	1.69
PTC + DE-H_2O/LiBr	2.30	2.38	2.14	1.62
PTC + NH_3/H_2O	2.33	2.51	2.30	2.88

Table 4: Maximum cost ratio per m² of collector area.

Conclusion

From the results obtained, the following conclusions can be drawn:

– On equal collector areas, ammonia/water heat pump powered by medium temperature collector is, no doubt, the most efficient air-conditioning system. In addition, from an economic point of view, this technology appears competitive if the collector costs are not greater than the values reported in the Table 4.
– On the other hand double-effect water/LiBr chiller, powered by PTC, shows a comparable performance with respect to the NH_3/H_2O heat pump in hottest climates.
– Finally, in warm climates the performances of single and double-effect water/LiBr chillers, powered by ETC and PTC respectively, appears comparable.

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Solar Thermal Air-Conditioning in the Frame of the German Funding Programme *Solarthermie 2000plus*

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INTRODUCTION

The Programme SOLARTHERMIE 2000plus, launched by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, provides funds for large solar thermal pilot and demonstration plants with collector areas > 100 m². Possible applications are combi-systems for heating support, industrial process heat support, district heat support and solar thermal air-conditioning. Participants of this programme may receive investment grants in the range of 30% to 50% of the total cost for the solar thermal system.

For each area of application, accompanying research measures are implemented in order to ensure a high quality level of the concepts. Fraunhofer ISE is responsible for the accompanying research in solar air-conditioning demonstration applications within this programme.

1 ACCOMPANYING RESEARCH

The accompanying research starts in the selection phase of the proposed installations by giving decision support to the Project Management Organisation Jülich (PtJ) on the quality of the proposed projects. The concepts are discussed with the proposer in order to avoid typical planning errors, which often have occurred in past installations. The proposed concepts are evaluated following a set of evaluation criteria, such as

- improvements to the building have been considered in order to reduce the cooling loads
- the cooling load profile is appropriate to apply solar air-conditioning
- the hydraulic concept allows a high utilisation of the solar thermal system
- solar heat is used throughout the year, assisting the cooling system as well as building heating and hot water preparation

If necessary, coputer tools will be applied for this decision support to verify the proposed system concept and system design on base of defined evaluation parameters.

The performance of the proposed concept and design is compared to the performance of a conventional non-renewable energy solution (e.g., air-conditioning with an electrically driven compression chiller) with respect to the differences in primary energy consumption and greenhouse relevant emissions.

Each of the installed demonstration and pilot plants in the funding programme will be equipped with a monitoring system, providing data necessary for

- the evaluation of the energetic performance of the system and assessment of the operation reliability and achieved environmental benefits
- the identification of weak points in the system control, causing unfavourable system operation and thus decreasing the performance
- allowing a comparative assessment of the installed plants.

This requires for a comprising monitoring of energy flux and electricity consumption of all relevant components in the system (solar thermal, cooling, heat rejection, hydraulic, etc.). The monitoring equipments will be installed and operated by research partners of Solarthermie2000plus, already experienced in the monitoring and evaluation of large solar thermal plants in the ancestor Solarthermie2000 programme: ZfS Hilden, Technical Universities Ilmenau and Chemnitz, and by the Universities for the applied Sciences Offenburg and Stralsund. In close collaboration with these partners, the monitoring concepts will be elaborated.

The results of the plant monitoring will be made available to the public at the project web page, including a final cross-section analysis of the installed plants. This documentation will serve as information source for manufacturers, planners and installers.

The accompanying research has also enabled organisational activities for the implementation of a new Task on 'Solar Air-Conditioning and Refrigeration' within the Solar Heating & Cooling Programme of the International Energy Agency IEA (1). This *Task 38* is in operation since October 2006. With the participation of Fraunhofer ISE (Operating Agent), the experiences in solar air-conditioning from Solarthermie2000plus can be disseminated at an international level as well.

2 EVALUATION OF PROPOSED CONCEPTS

The design task in the planning phase of a solar assisted air-conditioning system is to identify an optimum configuration and system size, leading to lowest system cost at highest environmental benefits. Evaluation criteria such as collector efficiency, solar coverage of the heat demand in the process, collector yields are useful to assess the technical performance, but in general do not indicate an optimised system size by their own. The same is true for investment cost and annual cost, which in general simply increase with system size.

A more appropriate evaluation parameter is the combined specific energy-economic performance indicator $C_{PE,saved}$, indicating the difference in annual cost per saved primary energy unit in comparison to a conventional reference system:

$$C_{PE,saved} = \frac{C_{sol,year} - C_{ref,year}}{E_{PE,ref,year} - E_{PE,sol,year}}$$

The annual cost $C_{sol,year}$ of the solar assisted system and the annual cost $C_{ref,year}$ of the reference system comprises capital cost (by annuity method), operation and maintenance cost. A condition is that the difference in annual primary energy consumption between the reference system and the solar assisted system ($E_{PE,ref,year}$–$E_{PE,sol,year}$) is > 0. For a given solar air-conditioning application, the above defined performance indicator 'cost per saved primary energy unit' often lead to a minimum when displayed as a function of the collector and storage size, thus indicating an optimised system size. Under the current cost situation, even the minimum value of $C_{PE,saved}$ is positive, thus revealing higher cost of the solar assisted solution. More details can be found in (2).

The precision of the balance volume of the application is essential, to interprete the evaluation results. Fig. 1 shows the system borders for the energy balance (and thus for the primary energy consumption) in an example, consisting of a solar assisted air-conditioning system with a thermally driven chiller and a gas boiler for heating and cooling. The reference system in this case in an electrically driven compression chiller (air-cooled in this example) and a gas boiler.

3 Large scale system installation

The first approved demonstration application on solar assisted air-conditioning in this funding scheme is currently in the planning phase. 1200 m² of vacuum tube collectors will be applied, to provide heat for assistant operation of an existing adsorption cooling plant for office cooling of the Technology Centre at FESTO AG, Esslingen/Berkheim. The Technology Centre is an energy-efficient office center with 26000 m² of air-conditioned area. The building is heated and cooled mainly by means of a supply/return air system and through concrete core activation. Currently, two heat sources are available: gas boilers and use of waste heat of approx. 600 to 800 kW capacity from the production facility. While in winter free-cooling via hybrid cooling towers is applied to cool the IT areas, the cooling demand of the offices in summer is covered by running three adsorption chillers of 400 kW chilling capacity each. Additional cold production is obtained also from ground piles. The vacuum tube collectors will act as a third heat source for the adsorption plant, thereby lowering the amount of required fossil fuels.

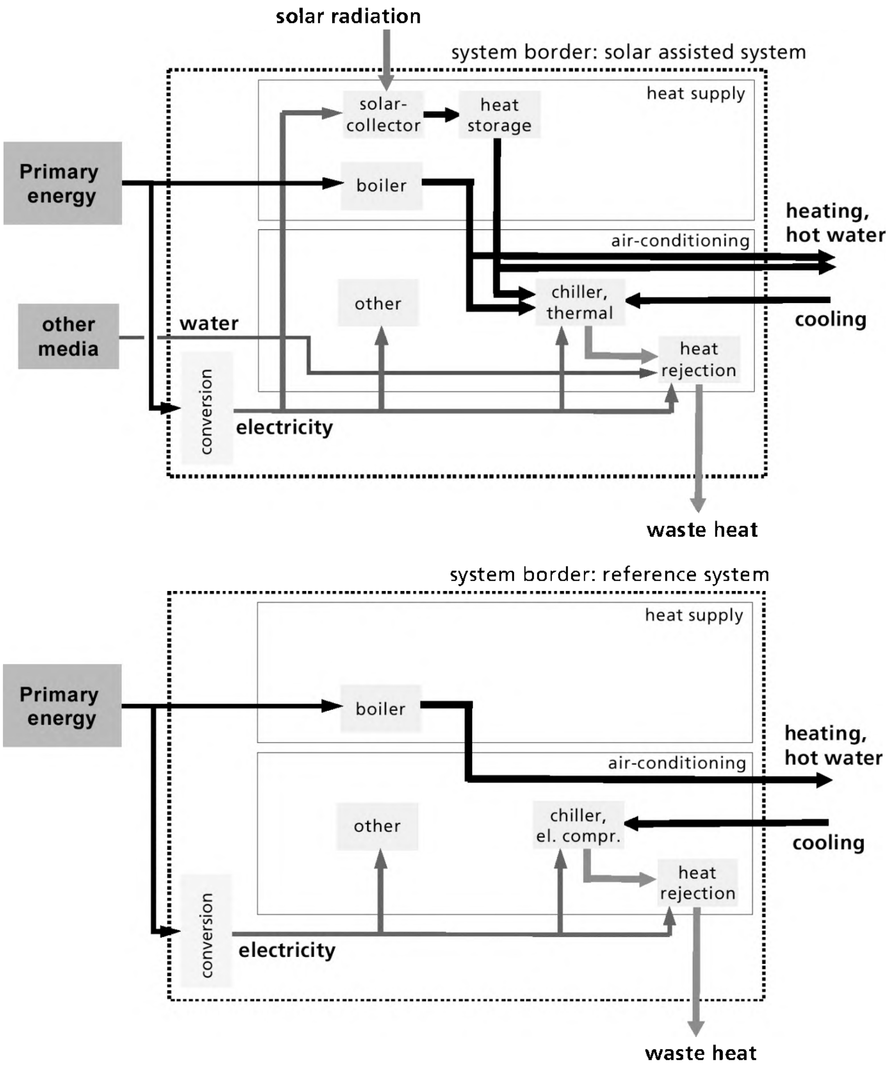

Fig. 1: Example: balance volume for energy and mass flow for a solar assisted air-conditioning system (top) and for a conventional system configuration (bottom). The total energy input for heating and cooling and for other auxiliary purpose is considered and compared.

Fig. 2: One of three adsorption chillers (manufacturer: Mayekawa, Japan) used for air-conditioning of the FESTO Technology Center.

Pre-design calculations revealed that the solar coverage of the heat demand of the chilling plant is in the range of 15% of the annual heat input. The size of the collector and thus the contribution to the required heat input is limited for the following reasons:

- limited available roof area for the installation of the collectors
- in general little experience with vacuum collector areas of this size
- avoidance of interference with waste heat usage.

Furthermore, in the context with the installation of the collector system, measures are foreseen to increase the waste heat temperature from 65°C to 70 °C or above, to allow in combination with driving heat from the solar system at the same temperature level an increased operation capacity and efficiency of the chillers.

The solar thermal collector system is planned to be installed in summer 2007.

Outlook

First proposals are approved and the systems are currently in the planning phase. The systems range from large scale to small systems with approx. 20 kW chilling cpacity. The application of new chiller types of medium and small size capacity in some of the expected installations is of special interest. Through the participation in the new Task 38 of the IEA, the transmission of the results at an international level is assured.

References

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Modelling of a Solar Combi-Plus System for residential and small commercial applications

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Since over one year Eurac research is monitoring one of the first small scale solar cooling systems installed in Italy. This "Solar-Combi Plus system" is used to assist the heating demand for a surface of about 1000 m² and satisfies the cooling demand for a reduced surface of about 400 m². In doing so a 150 m² flat plate solar collector field, an absorption chiller (EAW 15 kW), two 8000 l buffer storages for heating, one 1000 l buffer storage for cooling and a 600 l storage for sanitary purposes are installed. To satisfy the remaining needs of thermal energy both a gas and an oil heater are used. The hydraulic scheme – in cooling mode – (Fig. 1) as well as a picture of the building including a cut-out of the cellar (Fig. 2) are displayed below.

In June 2004 a monitoring system could be put into operation. With this the operability of the whole system has been confirmed and the data collection has started. [Besana et al, 1st International Conference in Solar Air Conditioning, October 2005, Kloster Banz, Germany]

In order to optimise dimensioning and design a masters thesis is carried out modelling the system and its utilization through the simulation-software TRNSYS. Therefore the monitoring system has been optimised and the data collection starts with the new cooling period beginning in May 2007. The already existing data were used to validate the TRNSYS model, especially for the adaptation of the Type that is used to represent an absorption chiller (Type 107).

Further information on the system and the simulation are available to download at the following address:
https://www.eurac.edu/Org/AlpineEnvironment/RenewableEnergy/index

At this place we would like to thank Stiftung Sparkasse for their support.

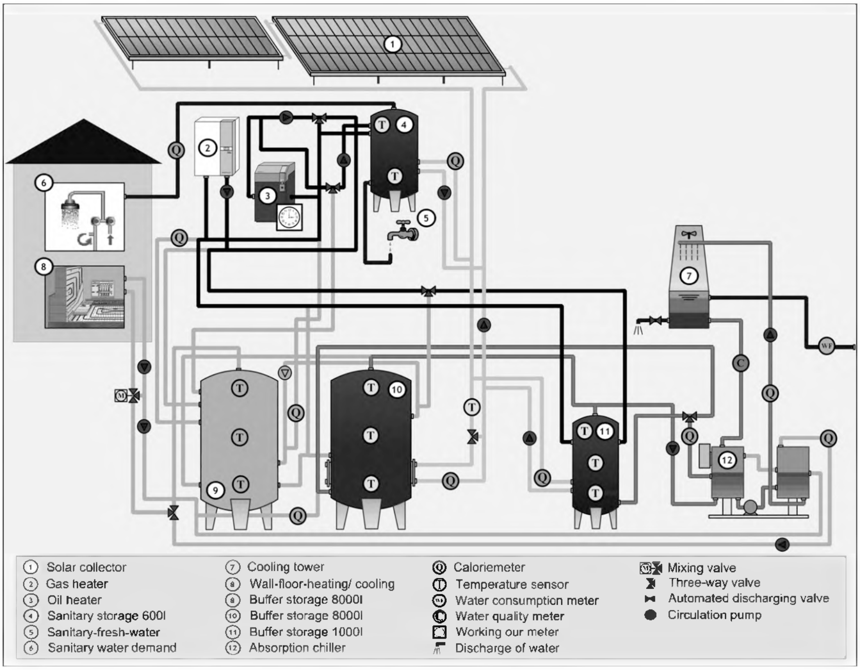

Fig. 1: Solar Combi-Plus system at the premises of Ebner Solartechnik

Fig. 2: Roof with flat plate solar collector field including a cutout of the cellar

Performance of Renewable-Only Heating and Cooling of a Modern Multipurpose Building

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INTRODUCTION

The *Kompetenzzentrum Solartechnik* of *Ingolstadt University of Applied Sciences* (Centre of Excellence for Solar Engineering) investigates the renewable-only based HVAC system of a multipurpose building. The 10,000 m² gross floor area building is part of the biggest logistic-centre in the region serving the *AUDI* automobile production facilities. On the one hand, the investigation is supposed to demonstrate the potential of solar-assisted cooling, on the other hand, the monitoring, financed by the *Bavarian Ministry of Environmental Affairs*, focuses on the total energy balance of the building and the various innovative building technologies.

Next to a ground source heat pump plant for base-load heating and cooling, the building is equipped with two arrays of solar-thermal flat-plate collectors (100 m² of *Conergy*, Germany, and 180 m² of *Solahart*, Australia) and a desiccant air-conditioning system (DEC, *WOLF Anlagen-Technik*, Germany). This consists of two plants with an air flow of 8,000 m³/h and a nominal cooling capacity of 42 kW each. One of the two plants is monitored. The plant itself is considered a black box in a first approach, i.e. all incoming and outgoing energy flows and the air condition are measured. Apart from the investigation of the performance of the solar-assisted air-conditioning system, the feasibility of DEC-operation using flat-plate collectors available on the market is investigated.

LEVEL OF COMFORT IN THE BUILDING

The level of comfort in six exemplary rooms is illustrated in the array of comfort in Fig. 1. It shows that the temperature in June and in July was slightly too high in some cases (1 ... 2 °C). However, 58% of all measured data in the rooms are in range of 'comfortable'. Another 24% are in the range of 'still comfortable'. Only 15% of the room conditions during the measurement period state 'uncomfortable warm conditions' and only 3% are in 'uncomfortable humid'.

Hence, the evaluation shows basically comfortable conditions in the rooms. Nevertheless, there is still some potential for optimisation. In winter, humidification of the rooms by the DEC-plant will help to improve the conditions while in summer the climate was sometimes slightly too warm. Considering the ambient temperatures, these conditions are still acceptable. An improved DEC-plant performance, however, will help to smooth the peak cooling demand in the rooms and to reduce the temperature to comfortable room conditions.

Tragically, the described situation shows why the users could not realize the malfunction of the DEC-plant, since the room conditions were 'comfortable'.

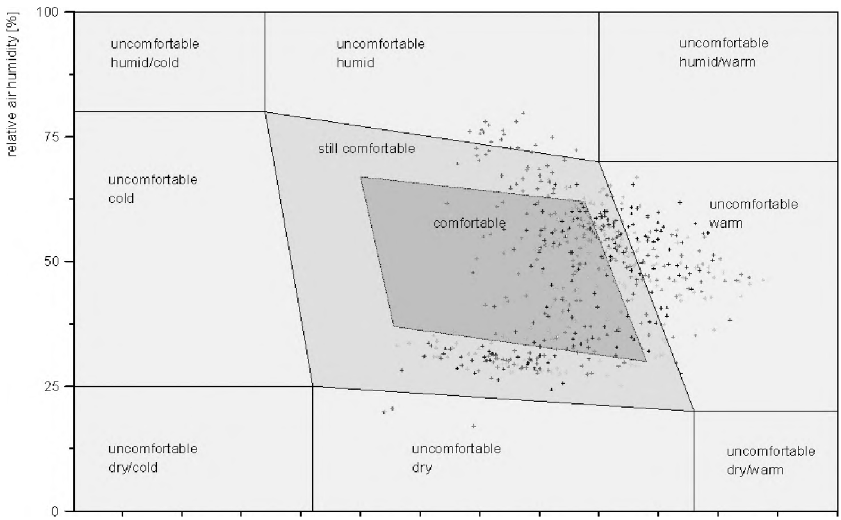

Fig. 1: Array of Comfort for June/July 2006 for Six Exemplary Rooms (different colours) in the Building

Performance of the Solar-Assisted DEC-Plant

An analysis of the energy flows in the building shows that the satisfying level of comfort was mainly achieved through the heat pump plant in combination with the activated building structure and wall heating/cooling devices. The DEC-plant which is supposed to supply peak-load cooling, however, increased the temperature of the supply air to the building as illustrated in Fig. 2 for June to September 2006. Although the plant was in cooling mode (regeneration air heater working), the supply air channel has a positive heat output.

A detailed measurement data analysis of all energy flows and air conditions of the DEC-plant shows the following most probable reasons for the malfunctions:

- The sorption wheel works at a too high speed due to a control malfunction. This leads to an increase of heat exchange from the return air to the supply air and a significant reduction of the dehumidification performance.
- The plant control uses the temperature of the supply and return air as control parameters so that malfunctions in the humidification/dehumidification cannot be detected during operation.
  Additionally, insufficient humidification was caused by calcinations of the supply air channel water injection due to dissatisfactory maintenance.
- The air volume flows in the supply and return air channels show significant differences which lead to unexpected behaviour of the DEC-plant.
- The controls of the DEC-plant and the heat pump with the building structure are not adjusted to each other. This results in a partly counterproductive operation of both devices as for example the target room temperature values in both controls are not the same.

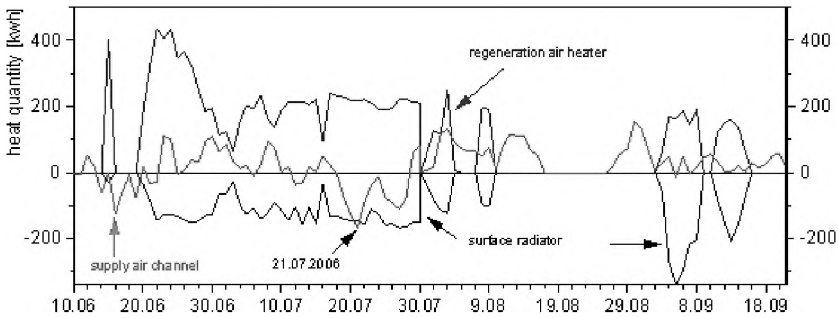

Fig. 2: Heat Flows of the DEC-plant in the Supply Air Channel, the Regeneration Air Heater and the Surface Radiator in June to September 2006

Application of Flat-Plate Collectors for Solar-Assisted Climatisation

In this building, solar heat is not only used to drive the DEC-plants but also for hot water preparation, for heating and to charge a voluminous thermal ground store. For that reason, high solar gains combined with high collector efficiencies can be expected. The geometry of the building made it necessary to split the solar-thermal collectors into two separate fields with their own control, however, using the same strategy to achieve a temperature level of at least 70 °C.

When looking at the results of the measurements, it has to be considered that both collector fields started to work after a winter break only in April for operational reasons. Furthermore, a number of deficiencies were found in the controls as well as in the hydraulics within the roof power centre where the collector fields are connected to the heat pump plant and the thermal store.

Even though, according to the data sheets, the performance of the *Conergy* collectors was expected to be superior to the *Solahart* collectors because of their particular design features such as for example an non-reflecting glass cover only a negligibly small difference in solar gain was measured.

As in so many cases, high-performance collectors can only demonstrate their capability in combination with the optimum system and an adequate control. In this respect, both collectors still have some potential.

Although the collectors were only operated for April to December, both fields did achieve a gain of about 265 kWh/m^{2}a, a remarkably high value for solar climatisation. This is because the solar heat is not only used to drive the cooling installation which is the case in most projects realized so far.

A typical measurement day in June is show in Fig. 3. This day is well-suited for a comparison of the two collector fields as both of them achieve the same total solar gain (related to the aperture area of the collectors). At an average temperature of 18.3 °C, a maximum temperature of 23.7 °C, a cumulated insolation of 6.75 kWh/m^{2}d at a maximum insolation of approximately 850 W/m^2, the collectors reached a solar gain of 2.83 kWh/m^{2}d. The volume flow of the *Solahart* field was about 15% higher than that of the *Conergy* field which, in turn, reached a temperature level 13 °C higher than the *Solahart* field.

Summary and Conclusions

During the first year of operation (2006), massive problems occurred in the operation of the DEC-plant. While the degree of comfort in the building was found to be satisfying during the cooling period, the DEC-plant showed major deficiencies in cooling performance, hydraulics and control. For example, although the plant worked in cooling mode, the supply air for the building was heated due to air leakage within the plant. Calcinations caused by insufficient maintenance blocked the water injection. Furthermore, an inadequate control of the sorption wheel speed was identified, so that the sorption wheel worked as a heat exchanging instead of a dehumidifying device. Apart from that, the DEC-plant control was not adjusted to the control of the base-load cooling by heat pump and building structure.

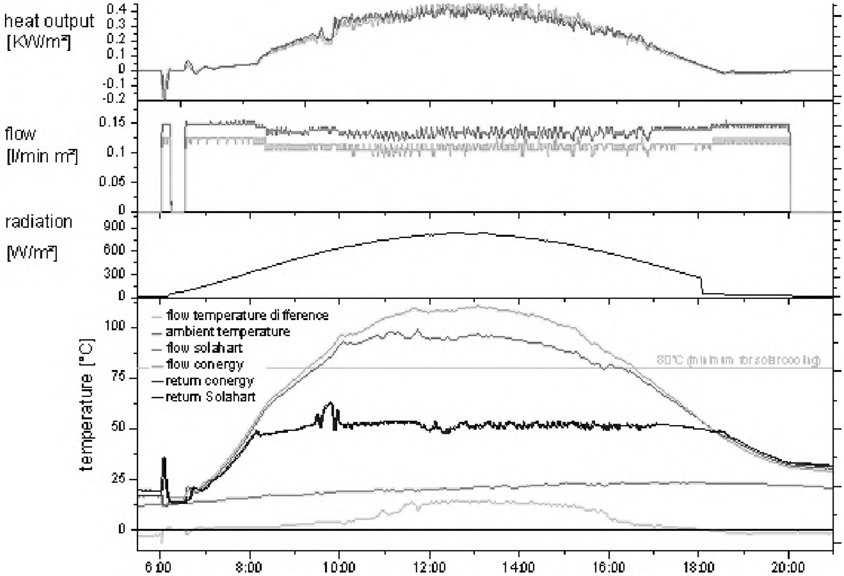

Fig. 3: Climatic Conditions and Behaviour of the Collector Fields on 11.06.2006
(Conergy: green curves, Solahart: red curves)

It appears particularly positive that both flat-plate collectors were able to reach the necessary temperature level of 60...70 °C for solar DEC-based climatisation even at moderate insolation of below 800 W/m² between 10 o'clock in the morning and 4 o'clock in the afternoon. The dimensioning of the collector fields, however, can only be judged after the forthcoming phase of optimisation.

In co-operation with the planning engineers and the manufacturer of the DEC-plant, optimisation approaches are now being derived which are to be implemented for the cooling period in 2007.

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